DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Acetylene and Britain

THE subject of acetylene manufacture from sources other than calcium carbide has been receiving a great deal of attention of late. In view of its importance as a starting material for the synthesis of a variety of chemicals such as acrylonitrile, acetaldehyde, vinyl chloride and for many valuable monomers, this interest is not surprising. The choice of the processes most suitable for Britain is a matter for speculation at the moment. In the U.S.A. a number of plants are known to be operating on the pyrolysis of natural gas employing either the Wulff or B.A.S.F. process (otherwise known as the Sachsse process), the so-called controlled combustion process, which has also been used for many years in Germany. One might pose the question why give consideration to non-carbide acetylene, when hydro-electric power in Scotland could perhaps be exploited to provide a home-based carbide industry—particularly when the production of acetylene from carbide is rather more suited to the needs of a variegated and scattered chemical industry like Britain's.

It is certain that for acetylene based on the B.A.S.F. process, the most popular alternative source of acetylene, a huge integrated undertaking is required producing ammonia for fertiliser manufacture apart from acetylene. For this process to be practicable an input of methane, or an admixture of it with other light hydrocarbons, of the order of 100 tons per day, is required. This points to refinery tail gas as the only suitable source of methane for Britain. Firedamp from coal mines, which has been discussed in this connection, contains too much nitrogen to be a sound proposition because the yield of acetylene would be so low. Moreover its sources are too widely distributed. It might also be argued that it would be a better bet to rely on ethylene as the starting point for the synthesis of this class of materials rather than acetylene.

Heavy Barley Water

THE ability of certain living organisms to concentrate particular chemical elements is well known; outstanding examples are provided by the seaweeds which can build up a relatively high concentration of iodine, the land plants which can absorb selenium to such an extent that they can become poisonous to browsing cattle, and sea squirts which extract vanadium from sea water. Certain mineral deposits are believed to owe their high vanadium content to the last-mentioned phenomenon. A partial separation of light and heavy water is brought about in some biochemical processes, as for example the photosynthetic process of the alga *Chlorella*. When germinating barley is steeped in water, the seeds apparently pick up light water more readily than heavy water, and this selective absorption has been studied by three scientists working in Stockholm. They have published their initial results in *Nature* (1956, Vol. 177, p. 988), and the extent to which the concentration of heavy water is increased by the selective activity of the barley is surprisingly high. They chose barley for their experiments knowing that these seeds in the malting process show a high capacity for imbibing water.

Computer Progress

IN many branches of Harwell's work complicated mathematical problems have to be solved, and many of the calculations that arise in reactor design, for example, could not be carried out without the aid of computers. One interesting exhibit we saw at Harwell was Britain's first transistorised digital computer, known as CADET. This has a power consumption of only 70 watts and uses 320 transistors. At the moment this particular design of computer exists only in "breadboard," but a fully engineered design is now being built. Also noteworthy was the electronic reactor simulator—a device which simulates the dynamic behaviour of a small experimental reactor.

Elsewhere in this issue readers will find an article about computers and their use for processing chemical data. It is worthwhile for the smaller firms and smaller research units which cannot afford to instal their own computers to consider using the commercial computer services of such firms as Ferranti, Elliott, English Electric and Leo Computers, Ltd. It is also possible to get work done on the computers of the National Physical Laboratory, Teddington, on a routine fee basis.

Zone Melting

ZONE melting is a technique which sprang from the need for preparing very pure samples of germanium and silicon for use as semi-conductors, but its applications are by no means limited to this specific field. At Harwell, for instance, it is being used to obtain the very pure plutonium required for the study of the properties of alloys of this metal, a necessary initial step in the development of reactors using plutonium as the fuel. At the Chemical Research Laboratory, Teddington, the same technique is being exploited for the purification of organic crystals. In fact, it seems that the method is applicable wherever there is a difference in melting point between the pure substance and its impure form and where the solidus and liquidus do not coincide. The method is so sensitive that purities of the order of $1:10^9$ can be obtained for germanium which must be the purest substance known.

A further development was shown at this year's Physical Society Exhibition by the Services Electronics Research Laboratory, Baldock. The method is being used for producing bars of pure tantalum, niobium and similar refractory metals. One of the difficulties in making bars of these metals is that of finding a suitable material in which to contain them. The SERL method uses no form of crucible oil container. The bars are mounted vertically and the surface tension of the liquid metal in the molten zone is sufficient to support it without a container. The only disadvantage of this method is that the maximum

diameter of the rod of metal which can be refined is limited by the surface tension of the liquid metal. For metals with a high surface tension quite large rods can be used, but tantalum, with only a small surface tension, can be treated in rods not thicker than a pencil. The technique may well find wider application, though it must evidently remain a discontinuous process, which limits its possibilities as a large-scale method of purification. But as a batch process it is capable of considerable development to increase the scale of operation.

Extraction Plant Tours U.S.A.

THE Maldon manufacturers of extraction equipment, E. H. Bentall & Co. Ltd., are to be commended on their initiative. They have sent out on tour a mobile quarter-size model of their new extraction plant, and their itinerary takes in drug, chemical, essential oil, paint, leather and food industry plants for which their unit is particularly suitable. The machine operates on the worm-expellor principle, is especially suitable for oil and fat extraction and for reduction of the moisture content of almost any substance. It uses about a third less horsepower than that required by continuous worm presses. This equipment was designed originally for the treatment of agricultural products, but as so often happens with a successful design, its use has spread to many other fields.

The Chemical Engineering Exhibition

LAST month we referred to the need for a first-class specialist fair for the chemical industry at which perhaps chemical plant manufacturers could also exhibit. Since that note was printed the organisers of the 1958 Chemical and Petroleum Engineering Exhibition to be held at Olympia in 1958 have reported progress. The demand for space has been so great that the sponsors—the British Chemical Plant Manufacturers Association and the British Manufacturers of Petroleum Equipment—have had to book more floor space. The area available is being increased by 50% by taking the National Hall ground floor and gallery. About three-quarters of the total space has now been applied for by over 200 member firms. On the face of it, it appears that no existing exhibition hall in London would be big enough to contain an exhibition embracing both equipment and chemical products. All enquiries regarding space should be addressed to F. W. Bridges & Sons, Ltd., 641, Grand Buildings, Trafalgar Square, London, W.C.2. (Tel.: WHItehall 0568.)

The Coal Shortage

LAST month we made the point that it would be a grievous mistake for Britain to concentrate too much technological talent on atomic power and neglect the exploitation of native coal resources. We were glad to hear the same view expressed by Sir Harold Hartley when he introduced a Fuel Ministry press conference to the O.E.E.C. report on European power needs. He said that people are being blinded by the promise of nuclear energy, and that no one should forget that our prosperity for years to come will depend on coal. He foresaw disaster for Britain's economy if the drift from the mines continues. The report gives figures showing how Europe's energy gap is growing. By 1975 it estimates that production of primary energy in Western Europe would amount to only about 750 million tons coal equivalent, excluding nuclear power developments. That corresponds to about 63% of estimated requirements. Nuclear energy might provide 80 million tons coal equivalent, less than 8% of total requirements. Unless a special effort is made to tap all native fuels, vast quantities of coal and oil would have to be imported to fill the gap. The report says that the responsible authorities and the public must be made to realise the need for "a new outlook on coal."

Filling the Power Gap

IT is estimated that Europe will need to invest $144,900m. (nearly £51,750m.) between now and 1975 in developing energy sources. Primary energy sources will call for $10,500m. for coal, $1600m. for lignite, $20,000m. for waterpower and $10,000m. for crude oil and natural gas. Secondary energy sources will require $10,800m. for coke and gas, $500m. for patent fuel, $38,000m. for thermal electricity, $11,500m. for nuclear power and $7,000m. for petroleum production and distribution. In addition, $35,000m. will be needed for transmission and distribution of electric power. It was a team headed by Sir Harold Hartley which produced this report, and the fact that *The Times* came out with a strongly critical leader on it has aroused some lively comment in technical circles, for Sir Harold has been closely connected with that newspaper for the past twenty years! *The Times* thought the report erred on the side of pessimism and did not offer enough constructive suggestions. Actually, of course, there has been no lack of useful proposals for ridding Europe of the risk of a huge fuel and power deficit. What is required is the urgent implementation of the best of those proposals.

By 1975 nuclear reactors, says the report, might supply about 8% of total energy requirements. That figure was arrived at by extrapolation from the official estimates for the British programme of nuclear power, and there is a good prospect that actual achievement will considerably exceed the White Paper targets.

Shaping Future Technological Education

IT may seem a little odd to couple two of the names—Lord Cherwell and Sir Ronald Weeks—in the Birthday Honours List together (see p. 180), but in fact both men have played important parts in re-shaping the country's policy for technological and technical education. Lord Cherwell is perhaps the most influential scientist this country has ever seen, wielding his great power behind the scenes as Churchill's personal scientific adviser, not only during the period when Churchill was Premier but also before and after that time. A few years ago he used his influence and his position as Paymaster-General to great effect and aroused the Government to a realisation that plans had to be made and implemented swiftly if the output of qualified technologists and technicians in this country was to match the increasing demands of industry. We remember in particular the compelling way in which he explained to the House of Lords that Britain could no longer afford to continue without at least one "technological university" of M.I.T. or "Caltech" standard. It was discussions involving Lord Cherwell which killed the bad idea for organising an invisible "Royal College of Technology," a proposal which the Government was on the point of adopting as a major plank in its plans for expanding technical education, in spite of the fact that all the great engineering institutions had shot the idea to pieces. The Government withdrew the plan, and eventually came forward with the new scheme, whereby students taking approved courses at certain colleges of technology will be given a "Hives Award," or Diploma of Technology, as it

will now officially be called. It was Sir Ronald Weeks who, as chairman of the National Advisory Council for Education in Industry and Commerce, did so much to build up this new scheme after the "Royal College of Technology" idea had collapsed in ruins. Both Cherwell and Weeks have other claims to fame, but what they have done to promote technological and technical education is most important as it will affect the nation for years to come.

C.R.L.'s Uranium Researches

FROM the Chemical Research Laboratory comes news of the large volume of research work being carried out by that establishment on behalf of the Atomic Energy Authority. The laboratory's annual report (*Chemistry Research 1955*, H.M.S.O., 4s.) states that a quarter of its staff has been concentrated upon work connected with atomic energy developments. Investigations have been made on processes for the concentration and extraction of uranium ores found in Cornwall, Portugal and various parts of the Commonwealth. The researches have embraced a number of interesting processes. Among them are processes in which the ores are leached with sulphuric acid and the solutions treated by ion exchange as the means of uranium extraction. In another one ion-exchange resin is added to the ore pulp and extracting solution. The resin, after mechanical separation from the pulp, is treated with acid nitrate or chloride solutions to recover the uranium.

A new process for the recovery of gold from cyanide solutions has been developed which could revolutionise industrial technique. It has been found that gold and silver can be selectively absorbed from a normal gold mill pregnant liquor by certain weak base ion-exchange resins and can then easily be eluted by a relatively inexpensive reagent from which it can be recovered by electrolysis. The gold-producing industry is showing great interest in the new process, although considerable research needs to be done before the method could be worked industrially.

Chemical Engineering in the S.C.I.

THIS month the Society of Chemical Industry celebrates its 75th anniversary. The annual meeting will last a full week, and an imposing programme of lectures has been arranged describing the major advances and trends for which industrial chemists have been responsible especially in recent years.

The founding of the S.C.I. resulted from the famous 1880 meeting in Manchester, at which Mr. Eustace Carey stated that the main requirement for progress in the chemical industry was more skill in the construction of plant, and accordingly proposed that they should adopt the title 'Society of Chemical Engineers'. The majority, however, voted for the amended title by which this organisation has been known ever since.

The society's Chemical Engineering Group dates back to 1919, being formed three years before the Institution came into existence as the professional qualifying body. The membership of the group increased by over a hundred last year and is now approaching the 800 mark. This year's chairman is Mr. George Brearley. The new hon. secretary is Mr. J. L. Sweeten. He succeeds Mr. R. C. Odams, now one of the joint hon. secretaries of the Institution of Chemical Engineers. The group is currently very interested in safety matters, and a special sub-committee is busy working out ways of improving the dissemination of the available information on this important subject.

The Lid Off the H-Bomb

AFTER Academician Kurchatov's lecture at Harwell there is considerable curiosity about the possibilities of deriving useful power from thermonuclear reactions, but very few people outside the Atomic Energy Authority have any information about the experimental work with a bearing on this subject which has already been done in Britain. Fifty scientists from industry and the universities are now somewhat the wiser after attending the 'secret' conference at Harwell which was called to discuss these matters. It now emerges that the U.S. Atomic Energy Commission has already given 36 industrial firms permission to use semi-restricted data collected during the development of the H-bomb so that they can set to work on the peaceful uses of fusion.

Demand for Natural Gas

SOME of the more serious problems facing Britain's gas industry spring from the shortage of coal and its high price. Some carbonising plants have to use imported coal, and gas manufactured from oil provides another means of bridging the gap. In the context all the possibilities of using natural gas need to be carefully explored. Possibly chemical enterprises outside the gas industry should also consider natural gas, in this case not primarily as a source of fuel but as a starting material for a number of important chemicals.

The recent reading of two papers, one by Dr. J. Burns and Mr. L. J. Clarke of the Gas Board, and the other by Dr. G. G. Haselden and Mr. N. Barber of Imperial College, add interest to the subject. In their paper to the Institution of Gas Engineers, Dr. Burns and Mr. Clarke considered the available sources of methane, and possible methods of transporting it in liquid form from such sources as the Middle East oil fields. They pointed out some of the problems that have to be solved, for example, in the design of storage vessels and suitable craft for seaborne transportation, and they concluded that once the design problems are overcome, and provided that the natural gas can be bought at a low price, the practice of inter-continental transport to distribution centres in Britain could be made. The paper given by Dr. Haselden and Mr. Barber to the Low-Temperature Group of the Physical Society was devoted mainly to an examination of different methods of liquefying methane; for instance, they described an interesting new cascade cycle which they had worked out, for which an efficiency of around 40% was claimed. A plant for liquefying methane obtained from mine drainage gas was also outlined. The two papers together give the impression that a concerted attack on the technical problems involved would be well worth while.

I.C.I. Launching Isocyanates

THE Dyestuffs Division of I.C.I. has plans for producing a limited range of isocyanates. These will find a ready market; in particular the big rubber manufacturers are keenly interested in these materials, already in substantial production in the U.S.A. Their mention is perhaps the most newsworthy item in the I.C.I. annual report. This mentions that Billingham Division's butadiene plant at Wilton is well under way, which will make possible an output of 10,000 tons of butadiene copolymers. I.C.I. has already released to the trade development quantities of these products for evaluation for such purposes as rubber reinforcement and for oil-resistant applications. Plastics

Division's new plant will provide for a ten-fold increase in output of "Fluon". Overseas activities include construction of £3¼ million fertiliser plant in Rhodesia and a polythene unit at Rishra based on Indian-made alcohol.

In chemical engineering circles the 'term' automation is unpopular, but it is used in the I.C.I. report in a reference to the automatic control of explosives production in the Nobel Division. This word is applied in the same sense to the control of chemical and petroleum refinery processes in the D.S.I.R. report entitled "Automation" (H.M.S.O., 6s.), which is quite useful for the key chemical references it quotes.

Titanium News

THE reports that appeared in several daily papers gave the impression that the snag which arose at the Witton plant where I.C.I. makes titanium was rather more serious than it actually was. An explosion occurred in an experimental furnace melting titanium granules. In view of the fact that similar explosions have occasionally occurred in the United States, it was decided that extra safety measures must be introduced. This has now been done. The production furnaces were shut down, but within a month of the explosion all of them were producing again. Deliveries of titanium were scarcely held up at all.

The first American plant to produce titanium by a sodium reduction process has come into operation. This belongs to Electro Metallurgical Co. and is located near Ashtabula, Ohio. It is said to be the largest unit for the production of titanium sponge in the U.S.A. The I.C.I. process is not being used, though the possibility exists that other firms may take up this process under licence from Imperial Chemicals.

Titanium scrap cannot at present be recovered on an industrial scale. But the U.S. Bureau of Mines is optimistic about its experimental recovery process, which promises a 70% recovery of metal, claimed to be superior in quality to the purest titanium yet produced (by the iodide process).

The Homogeneous Reactor: A Challenge to Chemical Engineers

THE homogeneous aqueous reactor is one of the most advanced concepts yet envisaged, and it represents a great challenge to the ingenuity of chemical engineers. Harwell experts are most enthusiastic about this idea, though the development of a practical power reactor operating on this principle is bound to take a long time. A model illustrating the idea was demonstrated during Harwell's open days. In this particular design the fissile core would be an aqueous solution of enriched uranyl sulphate. Surrounding the core there would be a reflector or blanket formed by a slurry of thoria in heavy water. Heat would be tapped from both the core solution and the blanketing slurry, which would be kept continuously circulating. The slurry would be processed to extract uranium 233, which could then be used as atomic fuel. An experimental reactor to test this system has already been built in the U.S.A. and the feasibility of this advanced idea is being studied at Harwell, where the thorium-uranium 233 cycle is regarded as very promising. A pound jam jar-ful of thoria—668 grams to be exact—is theoretically capable of yielding power to the tune of 150 megawatts a day. Anyone who is interested in the details of the American experiments in this field cannot do better than read the account published in the reactor volume (Vol. 3) of the published proceedings of the Geneva atomic energy conference.

A Major Chemical Engineering Text

IN mid-June the first two volumes of "Chemical Engineering Practice" saw the light of simultaneous publication in Britain and the U.S.A. This *magnum opus* will be completed in twelve tomes. Though not an encyclopædia in the conventional sense, it is the result of the efforts of an 'encyclopædic workshop' that includes many of the most distinguished men in British chemical engineering, both academic and industrial. This enterprise's Diderot is Mr. H. W. Cremer. As general editor of the series, he started with the firm intention of relying on British authors to the utmost. In fact he succeeded in completing his plans for covering this very wide field without needing to call on any foreigners, apart from the Dutch experts from Amsterdam and the Hague, who contribute excellent chapters on pilot plants to the first volume. Throughout this work special emphasis is placed on the fundamental physio-chemical principles underlying processes and plant design. To handle the manifold editorial details which this project involved, Mr. Cremer has had as his *aide-de-camp* Mr. Trefor Davies, who has handled the myriad editorial details inseparable from a work of such magnitude. Volumes I and II will be reviewed in our columns shortly.

Expanding Melamine Output

THE increasing applications of melamine in industries as widely separated as textiles and electrical engineering has made necessary the extension and rebuilding of the Chester-le-Street plant of British Oxygen. When finished, the output will be about 10,000,000-12,000,000 lb. a year. The site of this factory close to Newcastle was chosen as it was an already developed site near a port and well placed for the main centres of consumption. Dicyanamide, the raw material for melamine, is imported from Norway. Melamine, first discovered 120 years ago by Liebig, remained a subject of only academic interest until 1935, when the production of resins derived by its condensation with formaldehyde was patented. By 1939 it had been demonstrated that the resins produced by condensing melamine and formaldehyde had certain advantages over the established urea/formaldehyde and phenol/formaldehyde resins—notably, improved water resistance, durability and electrical properties, coupled with lack of colour permitting the formulation of white and pastel shades in the finished end products.

More Selective Pesticides

AS crop protection has become more scientific, so the idea that insect pests could be destroyed by chemical blitzkrieg methods has become obsolete. Indiscriminate spraying with unselective chemicals can produce most serious long-term effects; a classic example was the use of tar washes in English orchards, which slaughtered many noxious insects but also had the effect of converting the red spider into a serious pest—a case of unnatural and undesirable selection, because it destroyed the natural predators of this creature, which had hitherto done hardly any significant damage in the average orchard. The trend today is towards crop protection chemicals which are less indiscriminate. Glancing through the preprints of the papers for the second international conference on plant protection meeting at Fernhurst on June 19-21, one could not help but notice how much more scientific this subject is today than it was a few years ago. The trend towards more discriminating insecticides was well brought out, for example, in R. L. Metcalf's paper on the rôle of systemic insecticides in world agriculture.

BCE 164 for further information

Victoria Instruments

victoria INSTRUMENTS

DEWPOINTMETER

Developed by British Coal Utilisation Research Association

SPECIFICATION:

The instrument consists essentially of a high quality Pyrex glass detector element bearing 2 Pt / Pt 13% Rh thermocouples in the hemispherical surface, and mounted on a probe 1 inch in diameter and 6 ft. long. Cooling air and compensating leads from the other end of the probe connect to a box (24 in. x 10 in. x 6 in.) of good quality hardwood fitted with Rototherm, double range voltmeter and millivoltmeter and a 5 range microammeter. All these instruments are first grade accuracy (B.S.S. 89) having spring mounted movements and are built into a single unit which is internally earthed.

Cooling air connections are of the "Instantair" type and all metal parts are chromium plated. Calibrations can be made in English or Metric units.

Overall weight—

Probe and leads	...	8 lb. (4 Kg.)
Box	...	30 lb. (14 Kg.)

BRIEFLY, the Instrument:

The probe is inserted into the gases under test and the detector element temperature is controlled by the admission of cooling air from some suitable source (e.g. a small compressor) to its underside. The two thermocouples measure this temperature. When the surface is cooled below the dewpoint of gases they also become the electrodes of a "cell", the conductivity of which is recorded on the microammeter.

The detector element is constructed in such a way that its temperature can be controlled at fixed temperatures below the dewpoint for long periods, and comparative measures of the amounts of sulphuric acid condensed out at any selected temperature can be made.

The instrument is of particular value in determining the temperature range over which corrosion by sulphuric acid may be expected.

Sole Manufacturers:

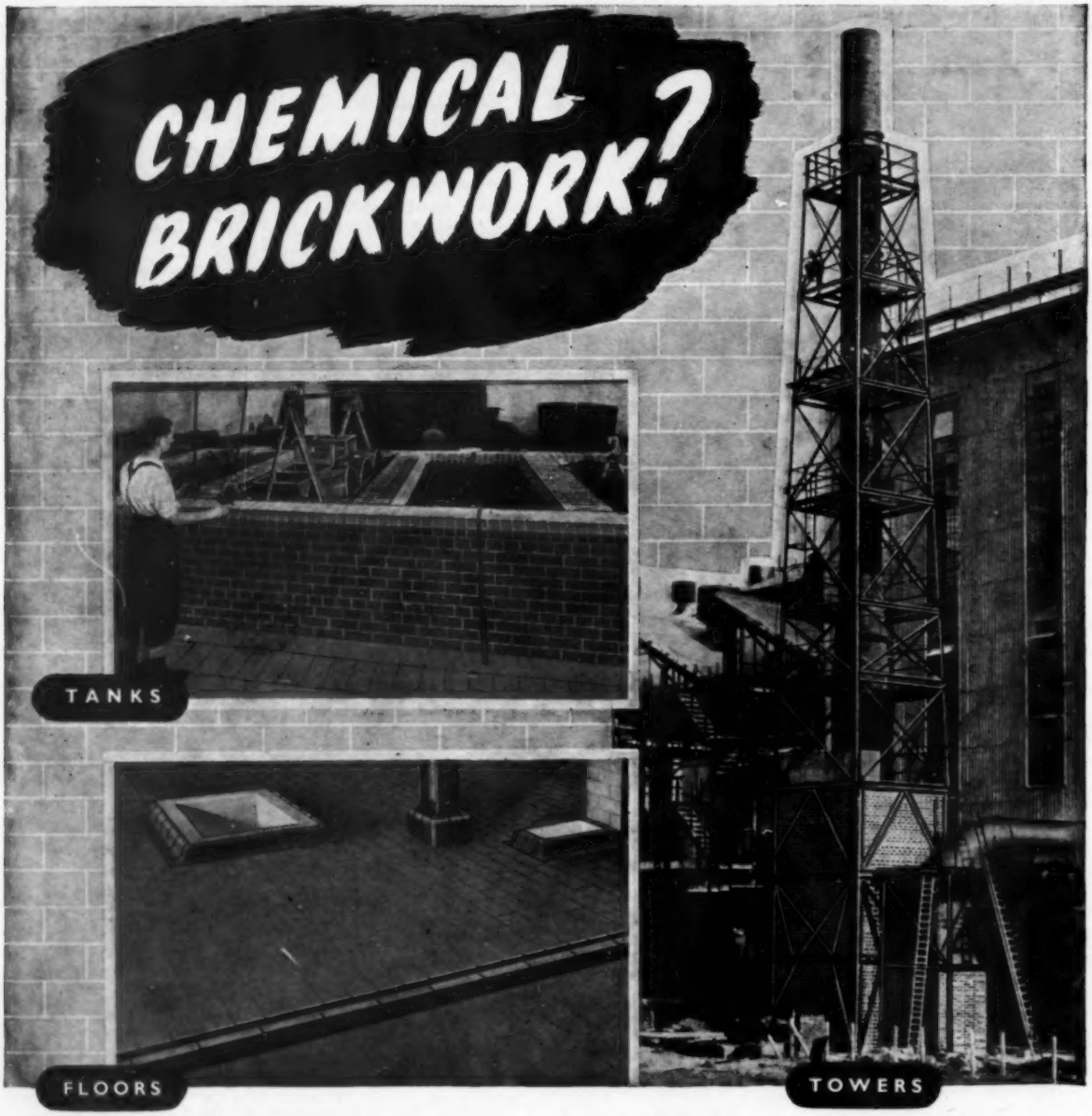
VICTORIA INSTRUMENTS

Proprietors: V.I.C. (Bournemouth) Ltd.

Midland Terrace, Victoria Road, London, N.W.10

Telephone:
Elgar 7871/5

Telegrams:
Vicmeter, Harles, London



CONSULT THE EXPERTS!

F. Haworth (A.R.C.) Ltd., have had over 50 years' experience as specialist contractors in chemical brickwork.

EXPERIENCE COUNTS!

Additionally they manufacture a complete range of acid and alkali resisting cements to withstand all corrosive liquors and gases.

Technical Advisory Service available

F. HAWORTH (A.R.C.) LTD.
Ramsbottom LANCS

Telephone RAMSBOTTOM 2067 & 3079. Grams: "CEMENTS" Ramsbottom

LONDON OFFICE
40, BUCKINGHAM PALACE RD.,
LONDON, S.W.1.
Phone: TATE GALLERY 3841
Grams: CHEMBRIX, SOWEST,
LONDON.

dm HW. 13

BRITISH CHEMICAL ENGINEERING
A HEYWOOD TECHNICAL PUBLICATION

Ten Years of Atomic Progress

TEN years ago the "first of the few" responsible for initiating the basic research and early development work for Britain's atomic energy project moved into makeshift buildings on Harwell airfield. This summer the completion of Harwell's first decade has been celebrated by a series of five open days, which provided between two and three thousand people from the universities, industry and the Press with an opportunity of seeing some of the work which this central research establishment of the Atomic Energy Authority is doing.

In many respects Harwell is to be regarded as an atomic university, but its research facilities are on a far bigger scale that one normally associates with a university, while most of the investigations it carries out are directed towards the obtaining of basic data which will be applied on an industrial scale eventually. In one respect in particular the approach of Harwell is more like that of a university than of an industrial research centre: the researchers can follow a scientific trail wherever it may lead, and they are not expected to drop an investigation at the point when it begins to yield new data for which no practical application can be visualised in the immediate or near future.

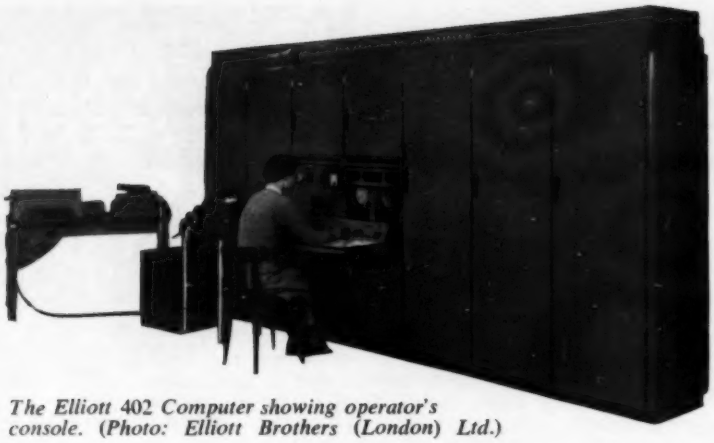
A host of practical applications have resulted from the researches of the Harwell scientists. The huge factories of Windscale, Capenhurst and Springfields, and the power station of Calder Hall, testify to the soundness of the stock of fundamental knowledge which was built up in the laboratories of Harwell. In 1946, when it became evident that further collaboration on atomic energy between the United States and this country would be greatly restricted, America had a long lead. For example, she was already producing plutonium, the fissile material of the bomb that blasted Nagasaki, in large quantities. Not only did Britain lack the physical installations in which to produce and extract plutonium and the "know-how" which can only be acquired through operating plants; we lacked even the fundamental chemical facts on which to base an industrial process for plutonium extraction. The essential chemistry had to be worked out from a small sample of plutonium—about as big as a pin's head—by Dr. R. Spence, now head of Harwell's Chemistry Division, and his team. I.C.I. chemists working at Widnes prepared flowsheets for the separation process, while Harwell accumulated other data required by the designers of the Windscale plutonium-producing reactors. The whole process of plutonium production and extraction was worked up practically from scratch and the Windscale Works was designed and brought into operation on schedule in a remarkably short period. The experience of being denied basic data about plutonium by the Americans was a bitter one, but Windscale demonstrated to the world that Britain could fully and swiftly engineer this complicated process without need to call in foreign technologists or "know-how". It established Britain's position as one of the three leading atomic powers in the world.

Great credit is due to the scientists and engineers of Harwell and Risley for the ambitious nature of Britain's initial atomic power programme. Calder Hall, the world's first atomic power station, will start pumping current into the Grid in October. Twelve more power stations of the Calder Hall types are planned to come into operation by 1965. Plans for much more advanced types of reactors exist on paper. Some of those who predict that progress in this field will be by revolution rather than by evolution cast aspersions on the Calder Hall design and refer to it as the "Tin Lizzie" stage in reactor development. But a good case can be made out for the belief that Calder Hall may well prove to be in the "Rolls Royce" class.

At Harwell the reactor experts led by such men as Dr. J. V. Dunworth are looking far into the future. They talk of Calder Hall as representing the first stage in reactor progress. They are already thinking about Stage II, which would include the pressurised water systems and sodium-cooled graphite moderated systems. With Stage III we should reach such projects as the fast breeder reactor and the homogeneous aqueous breeder reactor. No one is yet in a position to guess when the last two stages will arrive, but already Harwell is studying problems connected with all four of the reactor systems just mentioned.

One important Harwell project is concerned with the simplification of the processing of reactor fuel. At present the irradiated uranium fuel elements have to be put through a complicated and expensive process which starts with dissolving them in nitric acid. The idea on which the Chemical Engineering Division is working is this. The fuel will remain in the metallic state throughout. It will be melted at a high temperature and fission products driven off as vapour. The molten metal could then be used to form new fuel elements by casting. Preliminary experiments will be starting this month at Harwell to test the feasibility of such a process.

In the opening phase of the Atomic Age Britain has held her own, and a large measure of credit for that achievement must go to Harwell. But the pace of atomic progress is quickening and an almost unlimited number of promising lines of possible atomic development can be envisaged. In the next phase Britain has to accept the fact that she has no superabundance of scientific and technological manpower, and the A.E.A. will have to concentrate on the most promising projects. We shall no longer be able to waste precious manpower by setting two or three to teams at work on development problems that one team of the "critical" size could solve. In some fields it would seem more profitable for the A.E.A. to contract work out to existing industrial research and developments. This practice has been successful in the past, and judging from American experience it could be exploited more widely with considerable advantage. It would strengthen the ties between Harwell and industry, which would help to increase the speed with which basic discoveries are developed to the stage of industrial production. In this context the "capture" of Harwell men by industrial firms is a gain to the nation, even though it aggravates staffing difficulties inside the A.E.A. A "blanket" of Harwell men in industry could fulfil a valuable function somewhat analogous to that of the "blanket" in a breeder reactor.



The Elliott 402 Computer showing operator's console. (Photo: Elliott Brothers (London) Ltd.)

COMPUTERS FOR PROCESSING

TWO kinds of computer are currently the subject of intense study and development. They are described as analogue and digital computers. An analogue computer is essentially an electrical model of a non-electrical system; its output usually takes the form of a meter reading or a graph. A digital computer is essentially an apparatus for dealing with numbers treated as suitably coded patterns of electrical pulses. Its output usually takes the form of a printed page of figures.

A typical analogy between an electrical and a mechanical system is illustrated in Fig. 1. Fig. 1a shows a reservoir feeding through a head into a flush tank which periodically overflows by priming a siphon and discharging. Fig. 1b shows an electrical battery charging a condenser through a resistance. The condenser is in parallel with a neon tube which discharges at some critical value of the voltage across it and then continues to discharge down to a much lower voltage.

The two systems are analogous and at an appropriate level of complexity it becomes easier to observe the behaviour of a system such as (b) than to calculate the behaviour of a system such as (a). It thus becomes possible to set up an electrical model of, say, an oil refinery and thereby to test, for example, the stability of a stripping column to surging.

Analogue computers eliminate mathematics. Digital computers by contrast actually *do* mathematics. In preparing a problem for an analogue computer it is necessary only to draw the flow diagram of the system which it is desired to study, and then to set the computer up so that its circuit is analogous to that in the flow diagram. In preparing a problem for a digital computer a great deal more has to be done. The equations describing the behaviour of the system have first to be specified in analytical form. Then these equations have to be transformed so as to put them in a form where they can be solved by methods of numerical analysis. Finally the solution has to be "programmed for the computer."

In many but not all problems analogue and digital computers are complementary rather than competitive. Study of a problem by the analogue method generally induces a good physical insight into the nature of the problem and its solution. This insight, together with an approximate indication of the solution may be sufficient for practical purposes. This is frequently the case with problems involving the stability of feed-back loops.

If not, these studies with analogue computers may be invaluable preliminaries to more extended studies with digital computers. In mathematical calculations one frequently requires to subtract two numbers and use the difference as a divisor. If the two numbers are nearly equal, their difference will be nearly zero and the result of using such a difference as divisor will be very sensitive to error. Wherever this situation occurs digital computers come into their own. For analogue computers deal with physical quantities which are not usually measurable to better than about 0.1% or say one part in a thousand. Digital computers have unlimited accuracy but are usually limited to ten places of decimals; even so, they are a million times as accurate as analogue computers. When applied to essentially digital problems, as in accountancy, this accuracy may be required; it implies accounting to a farthing in ten million pounds.

Differential analysers, which have been widely used in the chemical industry, may be analogue or digital. They occupy a distinguished position among the various types of mathematical instruments which were embodied in the mechanical engineering phase of computation. Lord Kelvin visualised their possibilities but Dr. Vannevar Bush was

The Hec general purpose electronic computer. Left is the electronic unit; centre background the tabulator; right the Hollerith gang punch; and centre foreground the control console. (Photo: The British Tabulating Machine Co. Ltd.)

CHEMICAL DATA

by the Rt. Hon. The EARL OF HALSBURY, F.R.I.C., F.Inst.P.

the first to effect a reduction to practice. Modern differential analysers, however, are electronic and some (e.g. Northrop's Maddida) may operate digitally.

Digital Computer Operation

Operating a digital computer has certain resemblances to driving a motor car. One can drive a car without knowing much about its engine or other features; it is sufficient to know how it responds to accelerator, brakes, clutch, gear lever, starting switch and steering wheel. One can similarly programme a computer without knowing aught of electrical engineering; it is sufficient if one knows how the computer will respond to the orders it receives. A programme is typically a sequence of orders. Each order is typically of the form "Add A to B, and place the result in C." A, B and C are not the numbers used in the problem but coded indications of where those numbers are stored. "Add" is another number in a conventional code. "Subtract" or "Multiply" would also be represented by numbers according to the particular convention governing the digital computer in question. An order is thus a string of numbers. It is usually represented by punching holes in paper tape or cards, or by recording on a magnetic tape recorder. When the information recorded on tape or cards is converted into electrical impulses on a tape or card reader and fed into the storage system of the digital computer, the latter, on receipt of a signal to start, "obeys" the orders in succession and performs the sequence of calculations required of it.

It is impossible in the space of a short article to describe how this is done; suffice it that a computer is part clock, part automatic telephone exchange, part recorder, and part a counter (in a similar way to the counting portion of a geiger counter). It is not necessary to be a mathematician in order to programme a computer; it is only necessary to be a higher mathematician when the digital computer is required to do higher mathematics. Thus, to programme a computer for use in accountancy, it is only necessary to know what an accountant knows. In general a digital computer cannot be programmed unless the programmer can himself do the calculation with pencil and paper. Whatever an accountant can do with pencil and paper he can therefore learn to do on a digital computer. No mathematics over and above the simple arithmetic of accountancy are required.

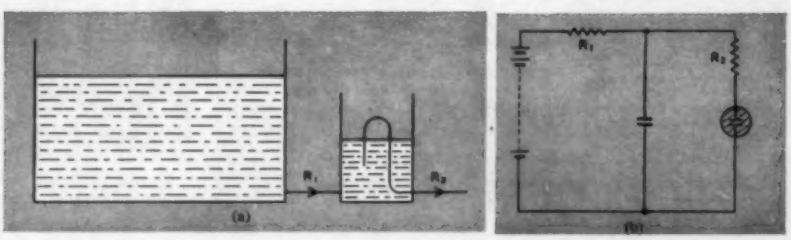


Fig. 1. Comparison of a system with its electrical analogue: (a) hydraulic system of reservoir, tank and siphen discharging device; (b) electrical analogue consisting of battery, condensor, and rear lamp discharging device.

Traditional and Non-traditional Calculations

Computers, particularly digital computers to which the remainder of this article refers, are thus new facilities for all to use. A new facility can usually open up from one to all of three opportunities:—

1. It may do a traditional job more cheaply;
2. It may do a traditional job better;
3. It may do some non-traditional job.

Traditional operations performed more cheaply include most of the operations associated with accountancy and statistics. These are frequently grouped together under the heading: "Data Processing." All classes of payroll calculations, including wages, tax, bonuses and deductions, may be conveniently carried out with a computer. The same computer will deal equally well with cost accounts, stock control, orders, invoicing and sales or general statistics. It is difficult to demonstrate the economies which will result from such a transformation in methods of data processing, because only very large organisations could show an economy of any one of the above items taken in isolation. Even the largest factory with 10,000-20,000 employees on the pay-roll would find that, properly used, a computer could only be kept busy on wages calculation for a few hours a day or one day in the week.

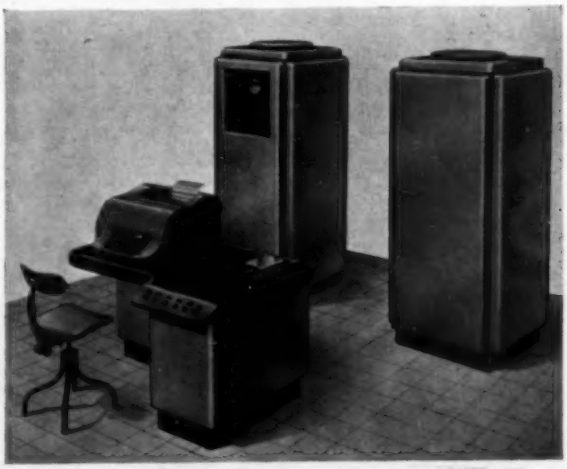
If a large computer were used for this purpose only and for no other, it would have to calculate wages for about 4,000 people in order to show an economy based on its being idle for 4¼ days out of 5. If, on the other hand, it could be put to work on four other problems of a similar magnitude, a factory employing some 800 operatives would achieve an economy, although the computer would still be idle for 3¼ days out of 5. The spare facilities available would, of course, be "free for all," particularly for the research, design, and development sections of a business, and as time on the computer was booked out to these users so the economies resulting from employing it on conventional operations would grow. What is certain is that data processing of the pay-roll, stock control, and invoicing variety is a feature common to all industries, and the chemical industry is no exception in this respect. In so far as computerised data processing is invading all industry, it will invade the chemical industry in like measure. A conventional data-processing problem peculiarly characteristic of the chemical industry is the analysis of process records. Computers are believed to have a wide field of utility in this context.

Miracle, the Ferranti computer which is working in the Shell Laboratory in Amsterdam. Above the operating panel.

Passing to traditional operations performed, not more cheaply, but better and more effectively, these will certainly include automatic control calculations, the stability of feed-back systems, stress and heat transport calculations and particular plant problems such as the design of fractionating columns. Analogue computers will certainly be useful, and possibly sufficient for the first two items in the list just given. Stress calculations are essentially laborious, so laborious that from time immemorial engineers have been in the habit of working to excessively high safety factors. The impossibility of using these methods in the design of aircraft has forced aeronautical engineers to work to much lower factors of safety than chemical engineers. The reduction of a safety factor from 6 to 3 would have a major effect on the capital cost of any plant concerned. If computers go only part way to achieving this sort of economy, they will pay for themselves without difficulty. Heat transport problems are another example of the engineer's inability to carry out the calculations he would like to, owing to their extremely laborious character. Of particular importance to, and distinctly characteristic of the chemical industry, are multi-product processes requiring the sale of a variable output

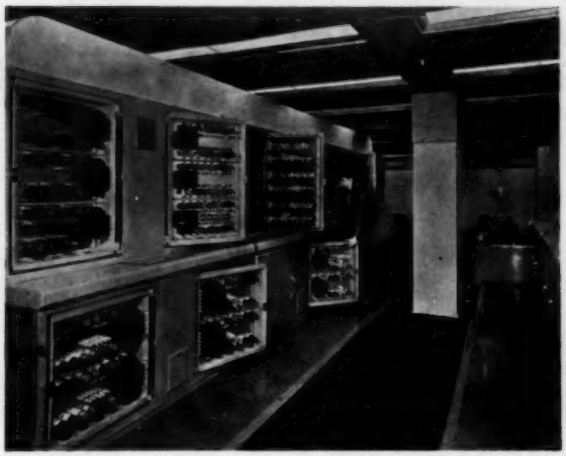
Problem	Mathematical Form of Problem Solved	Type of Computer Actually Used
Design of a reactor or converter, e.g. ammonia synthesis converter	Linear or non-linear differential equations	Digital. Mechanical Differential Analyser. Analogue*
Investigation of reactor system to find the optimum conditions of operation, i.e. simulation of a pilot plant	Linear or non-linear partial differential equations	Digital.
Determination of heat conduction under unsteady conditions, e.g. cooling of ingots, freezing of fish	Non-linear differential equations	Mechanical Differential Analyser. Analogue.
Investigation of dynamics of a chemical process in order to decide upon the best process control system	Non-linear differential equations Partial differential equations	Analogue. Mechanical Differential Analyser. Digital.
Separation by difference in diffusional properties, e.g. separation of U 238 from U 235	Differential equations	Mechanical Differential Analyser.

* *The term analogue is used here in the sense of Electronic Analogue Computer.*



The new Decca CI. View shows the operator's console with magnetic drum and arithmetical units at the rear. (Photo: Decca Radar Ltd.)

The monitor which gives an indication of the contents of Miracle's memory store; note punched tape on left.



Some of the complex electronic circuitry—of which Miracle is comprised. (Contains some 4,000 radio valves.)

of products marketed at different prices. Optimising the performance of such a plant so as to maximise the profits it earns is another example of a calculation so laborious that it cannot be adequately solved by traditional methods. It is characteristic of all these problems that they are solved by intuition based upon a preliminary inspection and confirmed by as good a rough check as time affords. Computers should transfer such calculations (for specific examples, see table) to a basis of greatly increased precision.

Included among non-traditional calculations made possible by the development of these machines are computations in the fields of X-ray analysis and molecular orbital theory. Conventional practitioners of organic chemistry are beginning to be overwhelmed by the structural complexity of newly discovered natural products and they frequently require the aid of the crystallographer. Computers scored their first big success in the crystallographic field by making a significant contribution to knowledge of the structure of vitamin B_{12}.

Organic chemists are being equally overwhelmed by the growth in the demand for screening the endlessly growing list of synthetic compounds for desirable properties. One problem of this type was recently solved, with notable success, by means of a desk machine; in this case the computer was used to determine from molecular orbital theory which of a number of alternative compounds of unknown character would have the properties of an anti-oxidant. Computers are likely to advance the application of this method considerably.

It would thus appear that the industrial organic chemistry of the future may depend less on the intuitive genius of the chemist and much more on the mathematical theorist.

What tools are available at what prices for all these classes of work? All electronic, fully programmable digital computers are but eight years old. The largest and earliest models were custom-built, one at a time, and they cost between £50,000 and £100,000. Such were the Ferranti Mark I*, the Deuce, the Edsac and the Leo in this country, and the Univac and the I.B.M. 700 series of machines in the U.S.A. A new generation of machines is now about to be marketed in the £25,000 to £50,000 range, each of which possesses some highly desirable feature. Such are the Elliott 405 (the most capacious for commercial operations), the Ferranti Mercury (the fastest for mathematical operations of great complexity), the Ferranti Pegasus (the most economical compromise for general mathematical purposes), and the English Electric Deuce (a very fast machine which is intermediate in character between the old and new generations). In addition smaller machines in the £15,000 to £25,000 range can be foreseen and some are already available. Such are the Hec general purpose computer (British Tabulating Machine Company Ltd.), the Elliott 402, and the Decca C1.† Thus, while performances have been increased, prices have tended to decrease and will doubtless decrease further. Rentals will probably establish themselves as a market develops.

All of the above machines (with the exception of the Decca C1) have either worked on chemical problems or have been ordered for this purpose. One British chemical company is said to have no less than five on order, and their allotted tasks will be distributed over the whole range of problems indicated above. The Ferranti Mark I at Manchester University has worked on crystallography and fractionating column design. A Ferranti Mark I, nicknamed "Miracle," is in whole-time use at the Amsterdam laboratories of the Royal Dutch Shell group of companies on problems of plant design, and on the reduction of infrared and mass spectra to analytical percentages. The Elliott 402 has also worked on refinery problems, process performance statistics, end-product control, fractionating column design, crystallography, and the assessment of an oil field's reserves. English Electric's Deuce has been concerned in molecular orbital calculations, the transient response of and multiphase equilibria in fractionating columns, operating process analysis and various problems in operational research.

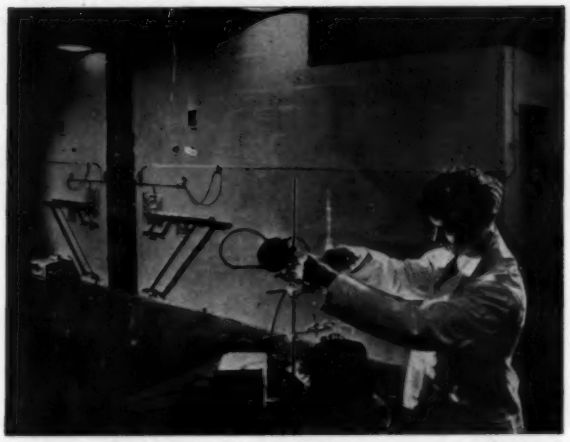
Thus in the first eight years of their existence computers have not only established themselves as potentially useful tools, but actually commenced to do useful work in the chemical and petroleum industries. In view of the formidable problems entailed in computer design, this is a truly remarkable achievement.

† This machine has only recently been announced. Details of performance have not yet been published.

READING LIST

1. W. D. Worthy, Institution of Electrical Engineers Convention on Digital Computer Techniques, April, 1956.
2. For a general account see "Faster than Thought" by B. V. Bowden, Pitmans, London, 1953; and A. D. Booth and K. H. V. Booth, "Automatic Digital Computers," Butterworths Scientific Publications., 2nd edn., 1956.
3. E. C. Long, "Stress in Long Pipes." Paper 96. Association for Computing Machinery. Philadelphia Meeting, 1955.
4. C. A. Levine and A. Opler, "Computer Solves Heat Flow Problems," *Chemical Engineering*, January, 1956, p. 203.
5. R. E. Gee, W. H. Linton, Jr., R. E. Maier and J. W. Raines, "Use of Computers in Kinetic Calculations," *Chemical Engineering Progress*, October, 1954, p. 497.
6. E. L. Albasiny, Institution of Electrical Engineers Convention on Digital Computer Techniques, April, 1956.
7. A key paper on the application of the differential analyser to partial differential equations involved in heat flow work is N. R. Eyres, D. R. Hartree *et al.*, *Phil. Trans.*, 1946, **240**, 1. See also J. R. Crank, "The Differential Analyser." Longman Green, London, 1947.

Monsanto's Radiation Laboratory



Setting up equipment against the background of the protective shield housing the radioactive source.

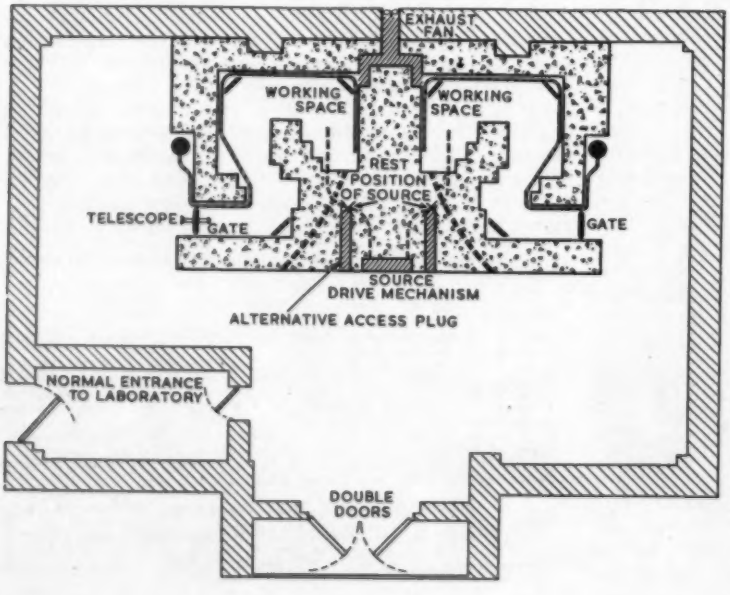
THE new radiation laboratory built by Monsanto Chemicals Ltd. as part of the recently opened Rideal Laboratories at Newport provides the first large industrial facility in Britain for research on radiation chemistry. This laboratory will not be using an accelerating machine as its radiation source, but pieces of cobalt made radioactive by exposure in a nuclear reactor. In the first place the two cobalt-60 sources used will have a strength of 100 curies. Later, cobalt sources of up to 500 curies and caesium-137 sources up to 1000 curies may be used.

The difficulty in handling radiation sources of this size is mainly that of protecting the laboratory staff from the ionising radiations. Whereas radio-isotope sources have the great advantage of simplicity compared with particle accelerators, they have the disadvantage that their activity cannot be switched off. The source must thus live in a cave surrounded on all sides by shielding material when it is not in use. Some suitably reliable remote control device must be designed for taking the source to the site of the experiment and returning it after use.

The plan of the Monsanto laboratory is shown in Fig. 1. Each radioactive source is in the form of a metal cylinder about 1 in. in diameter and 5 in. long, which is attached to a steel cable running through the central shielding block. Advantage has been taken in the design of the laboratory and source tubes of the fact that the powerful gamma rays emanating from the cobalt sources travel in straight lines.

It is well known that energy in the form of light, X-rays or gamma rays can bring about certain types of chemical reaction. In general this type of reaction is not of interest industrially, as conventional catalysts can usually be found which bring about the reaction more economically. There are special cases, however, in which radiation induced reactions are the only way of producing a certain substance. Gamma radiation offers special attractions because of the very high energy of the quanta. A wider range of reactions is thus possible as large amounts of energy can be released over small volumes of the reactants without appreciable increase in temperature of the whole.

One field in which radiation-induced reactions have already proved themselves is that of the cross-linking of polymers—particularly polythene and rubber. Considerable emphasis will be placed on this type of reaction by Monsanto, although other reactions including alkylations, halogenations, oxidations and isomerisations are being considered for investigation.



Plan of radiation laboratory. Note the ingenious design of concrete shield; there is over 42 in. of concrete between source and any point outside the shield.

SONICS IN CHEMICAL PROCESSING

Sonic processing is a promising technique for which a number of interesting applications, such as dust precipitation, have been developed. The liquid siren has potentialities in the preparation of emulsions in various industries.

by ALAN E. CRAWFORD A.M.Brit.I.R.E.*

THE term "Sonics" is now used to describe any form of processing by acoustic waves and covers the acoustic spectrum from sub-sonic frequencies to ultrasonic frequencies. Until recently, most of the work was done at ultrasonic frequencies between 15 kc/s and 5 Mc/s, but advances in transducer design and increased application knowledge has shown that in many cases there are advantages in the use of lower frequencies.

Sonics is still a young science, serious work in the ultrasonic field dates only from about 1930. In the early days it was thought that the largest field for exploitation would be in chemical applications, but although many laboratory tests showed great promise the method has not so far been applied to any great extent. The reasons for this are complex and are not easy to analyse. Until recently, two main factors contributed to the slow progress. The first is the large capital outlay required for high power equipment, and the second is the lack of knowledge of the processes involved.

*Brush Crystal Co. Ltd.

Fig. 1. Preparation of oil-water emulsion by means of ultrasonic whistle unit. (Courtesy Ultrasonics Ltd.)

During the immediate post-war years many hundreds of technical papers were published on the chemical effects that could be produced by the passage of an intense acoustic wave through liquids and extravagant claims were made that could not be substantiated in production tests. Although it was early realised that many of the effects in liquids required power levels sufficient to produce cavitation it was not appreciated that cavitation plays a vital part in causing the observed effect. Cavitation is always accompanied by a number of secondary effects and even now it is by no means certain which of these is the mechanism for producing individual results.

Apart from phenomena produced in liquids, there are a number of other effects in solids and gases which are of significance. With a solid, the applications are mainly confined to surface phenomena, while gaseous treatment has found applications in gas-liquid reactions and particle precipitation.

Applications of Acoustic Power

The prospective user of acoustic power is faced with an immediate problem when considering application techniques. There are a great many different methods of generating acoustic waves and the useful frequency range is from sub-sonic to ultrasonic. In terms of frequency this means from below 30 to above 5 million cycles per second. There is still controversy over the correct use of frequency for a particular application but recent work has done much to clear up this misunderstanding. As the frequency is increased, so the wavelength in a given medium decreases. For a given power output the amplitude decreases and the acceleration increases. These factors mean that the attenuation or power loss is increased with higher frequencies and the choice of frequency will be partially decided by the required power per unit volume. In a liquid the viscosity will affect the attenuation and this factor must be considered. It is obvious that beam divergence will be less with shorter wavelengths and this

simplifies the problem of applying power at a given point within the medium. Even at ultrasonic frequencies the difference in wavelength can be very large. For example, with water as the propagating medium a frequency of 25 kc/s will give a wavelength of 5.72 cm; at 2 Mc/s this will become 0.072 cm.

The choice of frequency is also governed to some extent by the type of transducer used. In most cases there are physical limitations encountered in their manufacture which restrict the operating range. Finally, in certain cases such as particle precipitation and agglomeration, it has been established that the wavelength and consequently the frequency will have a definite influence on the resultant effect.

Sonic transducers can be divided broadly into two classes; the first is based on the direct conversion of an alternating or pulsed electrical supply into an acoustic output, and the second utilises an initial mechanical, hydraulic or aerodynamic force for excitation of the transducer. The former type includes the application of piezo-electric, electrostrictive, magnetostrictive and electro-dynamic principles. The latter are mainly jet generators such as whistles, sirens and pulsed jets and these have achieved some success in chemical processing applications.

Use of Whistles

The use of whistles for the generation of sound waves in gaseous media at frequencies above the audible range is well known. Early studies of such whistles were made by Galton, and the original design is still used for "silent signalling" to dogs and for laboratory instruction. The basic design consists of a small circular cavity positioned opposite a concentric jet through which issues a high velocity gas stream. The frequency of the generated sound wave is mainly determined by the depth of the cavity which can be adjusted by means of a sliding piston. The system is somewhat akin to a closed organ pipe with the exception that the normal resonant wedge lip is replaced by the circular lip of the cavity. Under the influence of the high velocity gas stream, the vibration of the lip produces an edge tone composed of multiple frequencies. If the depth of the cavity is such that the natural frequency produced by its physical dimensions is included in the multiple frequencies, the air column in the cavity will vibrate and produce an amplified tone. Harmonics of the natural frequency will be present, but are generally very much weaker than the fundamental. The acoustic output of this type of whistle is very small and the multiple edge tones prevent its use for frequencies higher than about 25 kc.'s.

An improved version developed by Hartmann, using hydrogen as the medium, has generated frequencies in the order of 500 kc/s. The Hartmann whistle is similar in construction to that of Galton except that the annular jet of the latter is replaced by a coned jet.

With high gas pressure a jet velocity approaching the speed of sound will be reached and under these conditions a cross-over flow of gas will result. The critical pressure for such gas velocities is about 14 lb./sq. in. The cross-over effect is due to the occurrence of unstable regions of pressure, caused by oblique shock waves produced at the edge of the jet. These are inclined at the Mach angle, being reflected in changing direction at the point of meeting between the moving gas stream and the surrounding gas. By coning the inside of the jet chamber, the cross-over can be further reinforced by a side injection stream. If a resonant chamber is inserted into the jet stream at a position where a cross-over occurs, the gas in the cavity will be excited into resonance.[1]

Table 1. Particle Size for Resonant-Wedge Whistle Emulsifiers

Product	Type of Emulsion	Particle Size
Mineral oil 20% Emulsificant 0.5% Balance Water	Oil/Water	Up to 2 microns
Paraffin wax 10% Gelatin and gum 10% Balance Water	Oil/Water	3 microns
Liquid paraffin and agar	Oil/Water	2-3 microns
Hair cream	Water/Oil	Up to 2 microns
Salad cream	———	2-4 microns
Fruit essence	Oil/Water	Up to 2 microns

The efficiencies of energy conversion with such whistles are about 4%. The acoustic power output is usually 6 watts, but the system is rather unstable and cannot be operated for long periods without frequent re-adjustment.

The use of whistle systems is not restricted to gaseous media and a number of different forms of liquid whistles have been constructed. A design due to Crawford[2] is based on the Galton gas whistle and is shown in Fig. 3. The whistle is immersed in the liquid to be treated and this liquid is pumped under high pressure through the jet. The resonant cavity is adjustable in depth by means of a sliding piston.

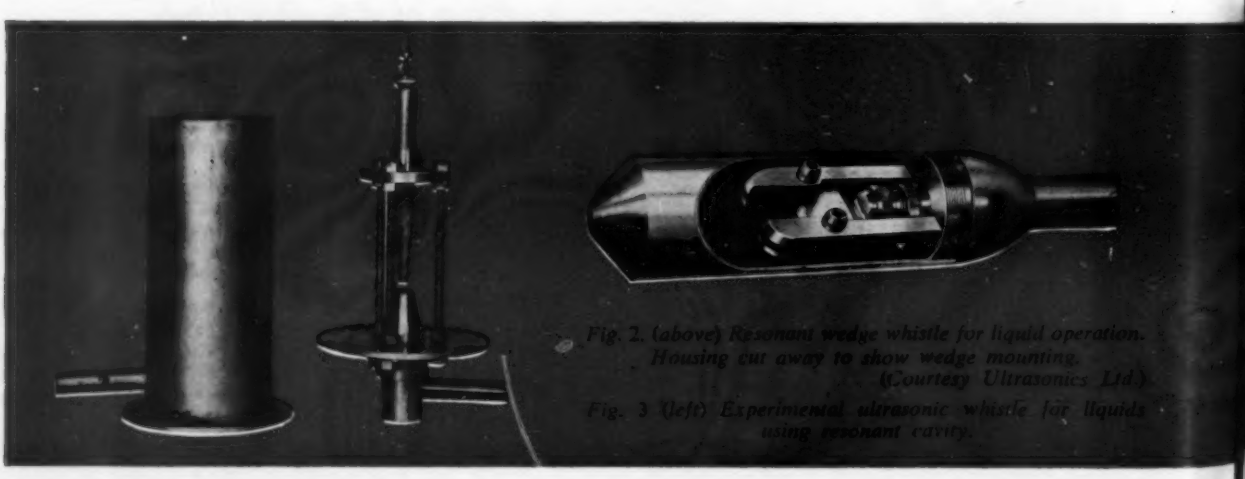


Fig. 2. (above) Resonant wedge whistle for liquid operation. Housing cut away to show wedge mounting. (Courtesy Ultrasonics Ltd.)

Fig. 3 (left) Experimental ultrasonic whistle for liquids using resonant cavity.

A resonant wedge whistle was developed by Pohlman and improved by Cottell. Here, a cross-over jet is used to excite a solid bar into its resonant frequency by allowing the jet efflux to play on an edge positioned at a cross-over point. An industrial version of this whistle is shown in Figs. 2 and 4. The jet is rectangular in shape and impinges on an end-mounted blade. This is mounted in a chamber acoustically designed to confine the propagated wave to the space surrounding the vibrating blade. An integrally mounted pump forces liquid through the jet at a pressure of between 150 to 250 lb./sq. in. and the pump inlet tube and whistle head are arranged for clamping to the side of tanks or other containers. Normally, generators of this type can produce acoustic levels of 1 to 2 watts/sq. cm, sufficient for cavitation to take place in the vicinity of the blade.

Considerable success has been achieved in the industrial application of these equipments and they are employed in many industrial processes for emulsification and dispersion. In comparison with other forms of transducer the whistle type generator is very efficient when employed for emulsification. The reason is somewhat obscure but it is thought that by forcing the unmixed liquids through an orifice under high pressure a rough dispersion will be produced before acoustic treatment commences. The surface area of the dispersed droplets will be very much greater than the static interface experienced in piston-type transducer treatment chambers. It has been shown that boundary layers promote active cavitation, and by increasing the area of interfaces present in the energy field the production of a stable emulsion will occur with greater rapidity.

The initial cost and output of resonant wedge whistle emulsifiers compare very favourably with the more orthodox forms of homogenisers. Rot-proofing emulsion for canvas is being produced at the rate of 2,000 gallons daily with an equipment employing a two horsepower motor driving the pump. Other uses include the manufacture of many pharmaceutical and cosmetic emulsions such as creams and cod liver oil mixtures. The food industry uses the equipment for the production of soups, sauces and salad creams, and fruit essences are also prepared for the soft drinks industry. Table 1 gives the final particle size quoted for this equipment.[3]

Siren Generators

A siren is fundamentally a means for producing pulses of liquid or gas at high pressure and consists basically of a rotor and stator supplied with ports through which high pressure pulses of the medium are released on rotation of the rotor. Although sirens have been used for many years to generate frequencies in the audible range, they can also be designed to produce high acoustic power outputs at ultrasonic frequencies. The unit designed by Allen and Rudnick[4] is typical of a siren for the generation of high frequencies. In this equipment air at a flow rate of 60 cu. ft./min. is fed to a chamber behind the rotor. This is driven by a variable speed motor at up to 340 rev./sec. Due to the high rotational speeds, the rotor has to withstand large stresses. It is, therefore, constructed from an aluminium alloy and its form is such as to produce uniform stress distribution throughout. Round the circumference there are 100 teeth, the width of each tooth being slightly greater than the port opening to ensure complete closing of all ports at the same time. The latter consist of 100 conically shaped holes and open into an exponential radiating horn. The efficiency varies between 17 to 32% over the frequency range 18.9 to 3.25 kc/s, with power outputs up to 176 acoustic watts. In a free radiation field an energy distribution of 1 watt/sq. cm is possible.

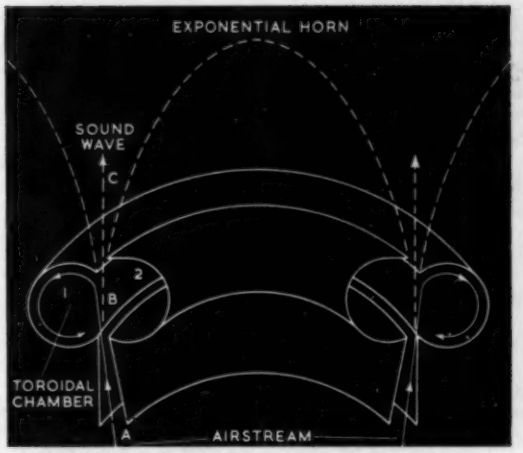


Fig. 5. Functional construction of static siren.

Sirens somewhat similar in construction are being commercially exploited in the U.S.A. for the agglomeration of aerosols. A number of models with different outputs are being produced, a typical unit giving 300 acoustic watts over the frequency range 1 to 5 kc/s, with a maximum operating frequency of 22 kc/s. Larger units have been built, one industrial unit having an output of 35 kW at 10 kc/s. An efficiency of 60% has been claimed for this installation and at maximum output about 10 watts/sq. cm would be possible over an area of 1,000 sq. cm.

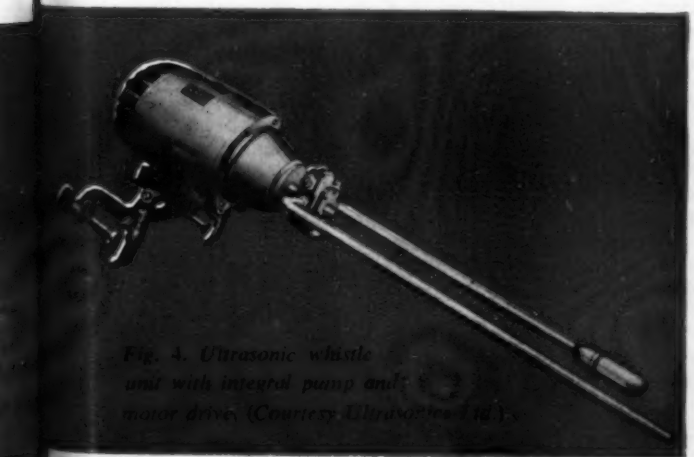
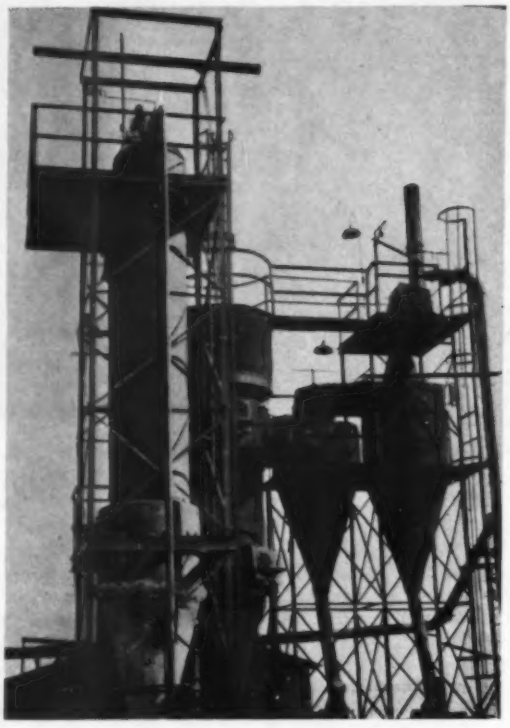


Fig. 4. Ultrasonic whistle unit with integral pump and motor drive (Courtesy Ultrasonics Ltd.).

Development in Static Sirens

A recent development embodies the features of both cavity resonators and moving-disc sirens but has no moving parts. Described by Levavasseur,[5] the unit resembles a conventional ultrasonic siren in external appearance, possessing an exponential horn for coupling to a gas load. At the base of the horn are two toroidal cavities, one being provided with a tapered lip, Fig. 5. A jet of gas (A) under high pressure enters the channel between the cavities and strikes the sharpened lip, being deflected in a path round the inside of the cavity. This air stream then crosses the path of the main jet near the lower end of the cavity (B), causing an interruption of the air flow. Since this flow is also maintaining the circulating air in the cavity, the action will result in pulses of gas being transmitted into the exponential chamber (C), similar in action to that of the circumferential holes passing a static port in a conventional rotating siren. The second cavity acts in push-pull



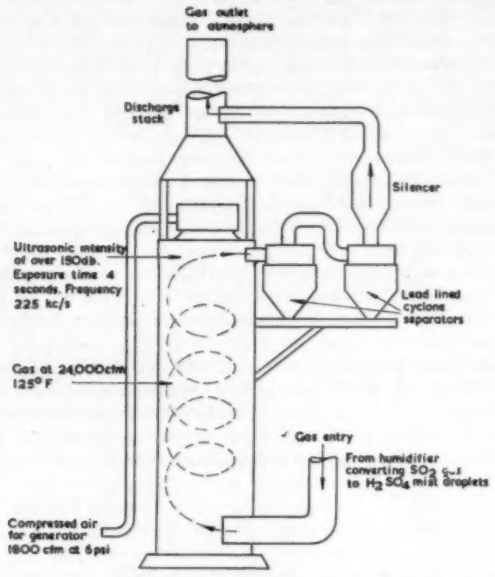

Gas outlet to atmosphere
Discharge stack
Silencer
Ultrasonic intensity of over 150db. Exposure time 4 seconds. Frequency 225 kc/s
Lead lined cyclone separators
Gas at 24,000cfm 125° F
Gas entry
From humidifier converting SO_2 gas to H_2SO_4 mist droplets
Compressed air for generator 1800 cfm at 6psi

Fig. 6 (left). Acid fog precipitation plant with sonic agglomeration tower and associated cyclones. (Courtesy Ultrasonic Corp, Cambridge, U.S.A.).

Fig. 7 (above). Schematic arrangement of acid fog precipitator using sonic agglomeration.

with the main chamber, increasing the pulsation effect.

The frequency of the generated sound wave will be dependent on the section of the resonant cavity and does not vary with an increase or decrease in the over-all diameter of the toroid. The output power depends on the gas flow through the jet and an increase in the toroid diameter will produce a corresponding increase in the sonic output with a given gas pressure. Practical tests have shown that high ultrasonic power outputs are possible with static sirens. One model with a chamber diameter of 30 cm and operating at 32 kc/s has produced a total acoustic power output of 474 watts. The siren required an airflow of 74 cu. ft./min. at a pressure of 36 psi. The over-all efficiency of conversion is therefore 10.8%.

Liquid Sirens

Rotating disc sirens can also be used for the production of acoustic waves in liquids and a number of experimental units have been made. In one version a drum type rotor is supplied with impeller blades and acts as a centrifugal pump, forcing the liquid through the radial ports in the rotor and out through corresponding ports on the stator. The siren is immersed in the liquid to be treated and is designed for operation in the frequency range 10 to 30 kc/s. In common with most ultrasonic sirens the system suffers from the disadvantage of rapid wearing of the ports and other surfaces. If high efficiencies are to be maintained, the clearances between rotor and stator must be accurately controlled. The high rate of fluid flow will cause extreme abrasive wear of surfaces due to the solid particles suspended in it. It is this factor that has so far prevented a wider employment of siren generators for production processes.

Particles Agglomeration in Gases

One full-scale production application of high power acoustic waves has been in the agglomeration of gas-borne liquid and solid particles. It is necessary to establish a standing wave field within the precipitation chamber in order to produce agglomeration. The phenomenon of sonic agglomeration is complex, being made up of a number of distinct actions. When a transmitted sound wave strikes a boundary surface the phase relationship of the reflected and outgoing waves depend on the dimensions of the system. Under certain conditions, the combined wave motion will reach a state of equilibrium and this is known as a standing wave condition.

At various points along the wave train, depending on the frequency and the length of the traversed path, there will be points of maximum amplitude known as antinodes. Conversely, there are also points of inactivity or nodal planes where the wave motion is zero. In a static system there is a movement of solid particles towards the nodal planes and this can be demonstrated in the well-known Kundt's tube. Since the gas column is under vibration the particles will follow the vibration amplitude to a certain extent, dependent on the particle size and the frequency imposed on the gas column. At low frequencies and small particles, the amplitude will be the same as that of the gas. As the frequency is increased, the inertia of the suspended particles will also increase and their imposed amplitude becomes less. It will be seen, therefore, that a state will eventually be reached where the particle becomes stationary and the gas stream will move past it. As this stage is approached, different sized particles will vibrate at different amplitudes and at varying phases.

When two particles are separated by a distance of only a few diameters, hydrodynamic forces of repulsion and

attraction are set up, caused by the restricted flow of gas between them. It can be shown that such particles will be subjected to two forces; a repulsive force in the direction of the vibrational wave causing the gas flow, and a force of attraction at right angles to this wave. It has been noted that particles will agglomerate in single planes and the produced surface will set itself at right angles to the vibrational direction. In a standing wave system, these flocs can reach a size of several centimetres.

The radiation pressure, which produces movement of particles towards a static region, will be determined by the sonic intensity. The size of the particle surface will influence this effect. Under the influence of a sonic intensity capable of imposing an amplitude of 50 microns on the particle and at a frequency of 20 kc/s, a sphere the density of water can be suspended against gravity. Agglomeration can thus be stated to be directly attributable to a combination of particle vibration, repulsion and attraction between adjacent particles and radiation pressure caused by the sound wave. The critical factor is sound intensity and the rate of flocculation is approximately proportional to the particle concentration per unit volume of gas.[6]

The American Ultrasonic Corporation have given orders of magnitude for power requirements in industrial plant. An average intensity of 160 dB is generally used, equivalent to about 2 watt/sq. cm of sound intensity. For a cross sectional area of 100 sq. in. this would require about 0.75 h.p. output from the sonic generator. There is obviously an economic balance between exposure time and acoustic intensity. This can be translated into equipment size and power requirements and tends to make large equipments economical, as the running costs and initial outlay are proportionally lower.

Industrial Plant Parameters

With these factors in mind, it is possible to establish design parameters for industrial plant. A sonic generator is required to supply energy densities of at least 1 watt/sq. cm. The treatment chamber should be resonant within a limited range of sonic frequencies depending on the fundamental generator frequency. The design of gas inlets and outlets should allow the maximum undisturbed gas flow, but at the same time prevent reflection or absorption of energy within the chamber.

Rotor type sirens and static sirens are at present used as the source of acoustic power in equipment manufactured for particle agglomeration, as other systems such as electrodynamic transducers cannot compare with the simplicity and power outputs possible with sirens. Generally, such agglomerators have been used where the particle diameters are less than 10 to 15 microns and where the concentration is not less than 2 gr/cu. ft. Additional advantages also possessed by this type of separator are its low-pressure risk where inflammable materials are handled, the wide temperature ranges over which it can be used, and its effectiveness in agglomerating and collecting particles in the micron and sub-micron ranges.

A system used for the precipitation of acid fog is shown in Figs. 6 and 7, and is employed in a contact type sulphuric acid plant. The efflux gases from a sulphuric acid absorption tower are converted from sulphur trioxide to sulphuric acid mist by passing through a jet type humidfying chamber. The mist particles are between 0.05 and 5.0 microns in diameter. A gas stream of 24,000 cu. ft./min. at a temperature of 125°F is introduced tangentially at the base of an agglomeration tower eight feet in diameter and 35 feet high. After treatment, the gas passes through cyclones for the final separation of any particles not precipitated in the tower and then finally to the atmosphere. An arrangement of baffles may also be used for collection, either individually or in conjunction with cyclone separators. A sonic intensity of over 150 dB is produced in the tower and practical operation of the system has shown that less than four seconds treatment time is necessary for the removal of over 90% by weight of acid from the gas stream. Fifty per cent of the acid is precipitated on the sides of the agglomeration tower and the remainder is removed in the cyclones. The atmospheric efflux then contains less than 3 mg of sulphuric acid per cubic foot of gas.

A similar equipment has also been applied successfully in the recovery of ash from flue gases in a paper mill boiler. Sonic agglomeration has been used for the recovery of carbon black in its manufacture from natural gas. Thus, one plant for this purpose operates at a frequency of 3.5 kc/s and it is claimed that 96% of the carbon black can be recovered by this means. A similar plant constructed in Switzerland uses a large static siren as the sonic source and has been running for some months under satisfactory conditions.

Conclusions

Future advances in sonic processing will depend mainly on the development of more efficient transducers. At the present time the efficiencies are poor and the equipment is not easily adapted for industrial application. Although jet generators show many advantages over existing electronic equipment, it is possible that they may be surpassed in performance and reliability in many cases by the use of the new polycrystalline ceramics energised by motor alternators at relatively low frequencies.

REFERENCES
1. Stevens, R. W. & Bate, A. E. "Wave Motion & Sound." Arnold, 1950. p. 330.
2. Crawford, A. E. *Research*, 1953, **6**, 106.
3. Crawford, A. E. "Ultrasonic Engineering." Butterworths, 1955.
4. Allen, C. H. & Rudnick, I. *J. Acoust. Soc. Amer.* 1947, **19**, 857.
5. Levavasseur, G. French Patent No. 1,039,511.
6. St. Clair, H. W. Conf. Met. Res., Met. Div., U.S. Bur. Min. Salt Lake City, Utah. 1940.

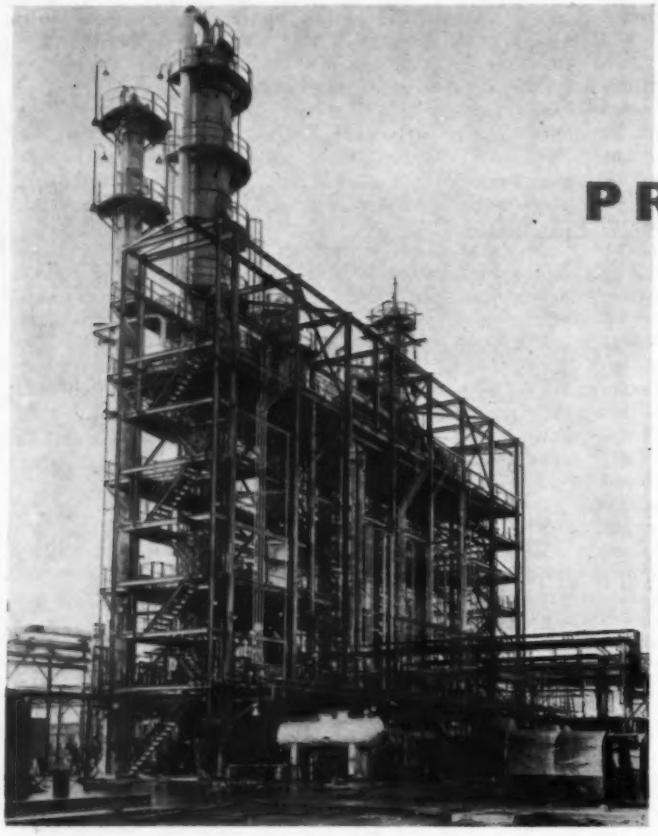
New Servicing Depot

New premises have been constructed at Billericay, Essex, for Humphreys and Glasgow Ltd. Among other purposes that it will serve will be the bulk storage of the special catalyst used in the ONIA-GEGI process. The depot is equipped with everything necessary for the servicing of construction equipment and tools and is stocked with contract materials in short supply. It has, furthermore, facilities for the assembly of components and for general testing and development work.

The site for the depot was selected primarily because it has good road and rail facilities with easy access to London docks for export. Humphreys and Glasgow have extensive overseas connections to which they export plant and equipment. A private siding has been constructed adjacent to Billericay Station between the main London-Southend (Eastern Section) railway line and the depot. Mechanised plant for offloading material and equipment is installed.

Plant for the manufacture of the catalyst used in the ONIA-GEGI Oil Gas process and similar, is an important feature of the new depot. Before the erection of this plant all catalyst material had to be imported from an associate company in France. Now all plant built by Humphreys and Glasgow in the future will be supplied with catalyst prepared in this depot.

A new modern testing and proving laboratory is scheduled to be erected shortly on the same site, and will be staffed by a highly qualified team who will undertake all laboratory scale work in the many fields in which Humphreys and Glasgow's activities are concerned.



PRINCIPLES OF

by N. W. ROBERTS, M.A., F.R.I.C.*

Fig. 1. *A typical large-scale gas separation plant.*

THE first low temperature plants were constructed for the separation of air. Before air can be distilled, it is necessary to remove nearly all the water vapour and carbon dioxide which it contains; otherwise the deposition of these compounds in solid form would soon block the plant and bring operations to a standstill. In the early plants, the carbon dioxide was removed by scrubbing with caustic soda, and the water by calcium chloride, but the inefficiency of these operations made the length of run before the plant blocked rather short.

The development of modern chemical engineering techniques has improved the efficiency of these chemical methods of purification, to such an extent that the length of run is now measured in months rather than in days. The constant operating expense involved in chemical methods has, however, restricted their application to the high-cost compressed gas market (where the cost of handling the cylinders far exceeds the cost of production of the gas). Attention has centred during the last twenty-five years on the development of physical methods, where the gas is purified by refrigeration, but the equipment is so arranged that the condensed solids do not permanently block the passages, but are continuously or semi-continuously removed.

Three types of heat exchanger are commonly employed in gas separation processes—regenerators, reversing exchangers, and non-reversing tubular exchangers. The use of the first two is restricted to relatively low pressures, while tubular exchangers are used for processes employing high pressures. Tubular exchangers tend to become less economical in large sizes. Regenerators and reversing exchangers have the advantage of being self-cleaning, so that the gas supplied to these exchangers need not be purified; its impurities are deposited on the surfaces of the heat exchangers, and later revaporised into the product stream by ingenious control of heat-exchange conditions.

The near-universality of the shell-and-tube heat exchanger in chemical and petroleum practice is due not to its heat exchange characteristics, which are by no means ideal, but to the fact that it can be easily cleaned. This is important, because as a general rule fouling is to be expected. In gas separation processes, however, while fouling does take place, and is indeed at least as important a problem here as in other industrial processes, the fouling agents are usually volatile at room temperature, and can be removed by the simple process of warming. The essential point is that such deposits as occur are purely temporary; tarring and scaling do not arise.

The type of tubular exchanger most frequently used is due to Giauque (Fig. 5). It is not usual outside the low temperature field, because once fouled by non-volatile materials it is impossible to clean. The arrangement is occasioned by the low specific volume of compressed gas, which makes it difficult to obtain in conventional arrangements the high velocity within the tubes which is essential for efficient heat exchange without incurring prohibitive pressure drops on the low pressure side. Readers will realise that Nature has somewhat unfairly provided that the lower the pressure the higher the pressure drop for a given mass flow of gas in a given arrangement. In order to overcome this difficulty, the high-pressure tubes are spirally wound round a mandrel, and the low-pressure gas is led across the turns in a direction parallel to the axis of the mandrel, so that at all times the flow of gas is nearly parallel to the tubes. In order to avoid spiralling of the low-pressure gas, alternate layers of high-pressure tubes are wound in

* Costain-John Brown Ltd.

GAS SEPARATION — Part 2

opposite senses. It is possible to tailor exchangers for a given duty by varying of the number and diameter of the tubes, number of layers, and their radial and axial pitch.

Regenerators work on exactly the same principle as the recuperators found in a blast-furnace installation. A large mass of material of high heat capacity is packed into a containing vessel. Cold gas is passed through it for a limited period, so that the mass is cooled. Warm gas is then passed through in the reverse direction for a further period, and it is itself cooled by drawing on the heat storage capacity of the cold mass. In order to secure continuity of operation, two regenerators are used as a pair, so that at a given instant, one is being cooled and the other warmed. The pipe connections used are shown in Fig. 4. It is usual in such plants to provide mechanically actuated valves controlled on a time cycle at the warm end of the regenerator, and poppet valves at the cold end.

Packing Materials for Regenerators

Various materials have been used from time to time for packing regenerators. In the blast furnace application, refractory brickwork is used, and indeed in high temperature applications the refractory properties of the materials used are the only criterion, since at high temperatures the atomic heat capacity of all materials tend to be the same. At low temperatures, however, considerable differences in heat capacity are found, and this is usually the determining factor. Aluminium is used in the Linde plants and is usually installed by winding thin discs of crinkled strip, as shown in Fig. 2, and stacking them in a pile in the containing vessel. Recent practice, particularly where pure products are required, is to use pellets since these allow coils to be fitted into the regenerators.

Reversing exchangers were developed in the United States during World War II, and since then have been principally used in plants of American design. Basically they consist of extended surface exchangers which are operated in a normal manner, except that when the impurities in the feed gas have deposited on the surface to the point of incipient blockage, a switch is arranged between the feed gas and one of the product gases, so that the deposited impurities can re-evaporate into the product stream. Piping arrangements are shown in Figs. 3 and 4.

The theory underlying the operation of regenerators and reversing exchangers is similar in principle, and the general remarks that follow apply to both. The purification effect is produced by allowing the impurities to deposit on the metallic heat-transfer medium as the gas is cooled, and then at a later time revaporising them into the product stream, so securing complete continuity of operation. The product stream must be appreciably colder than the stream of inward gas, otherwise there would be no temperature difference and heat exchange could not take place. At the

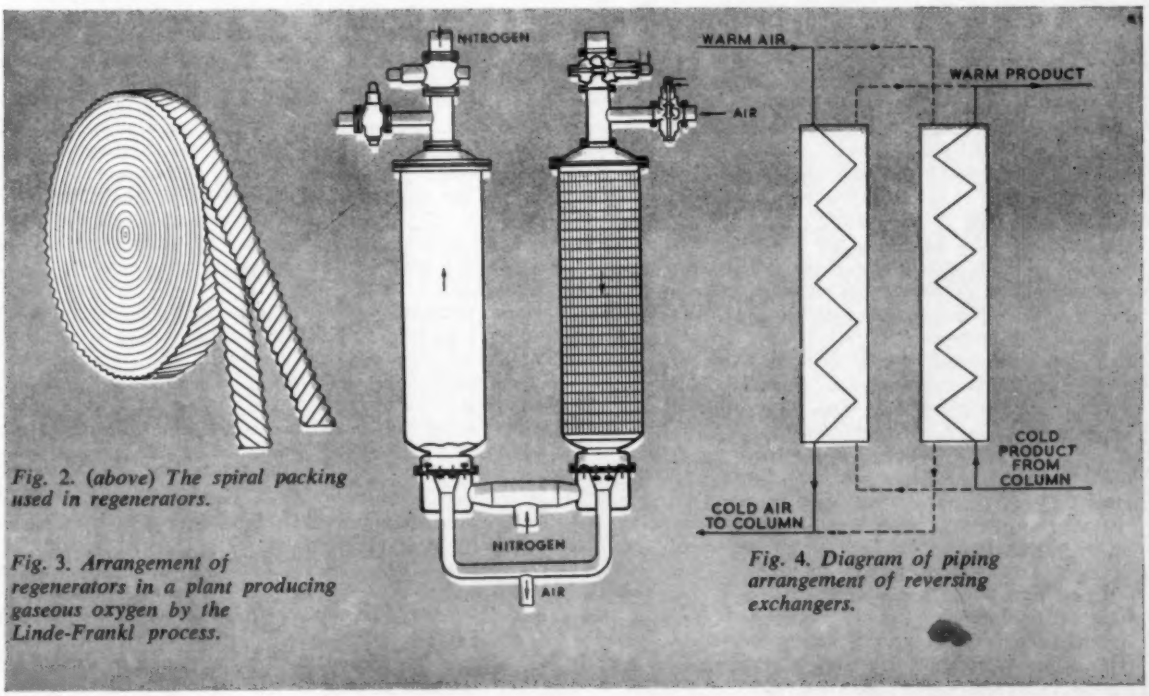


Fig. 2. (above) The spiral packing used in regenerators.

Fig. 3. Arrangement of regenerators in a plant producing gaseous oxygen by the Linde-Frankl process.

Fig. 4. Diagram of piping arrangement of reversing exchangers.

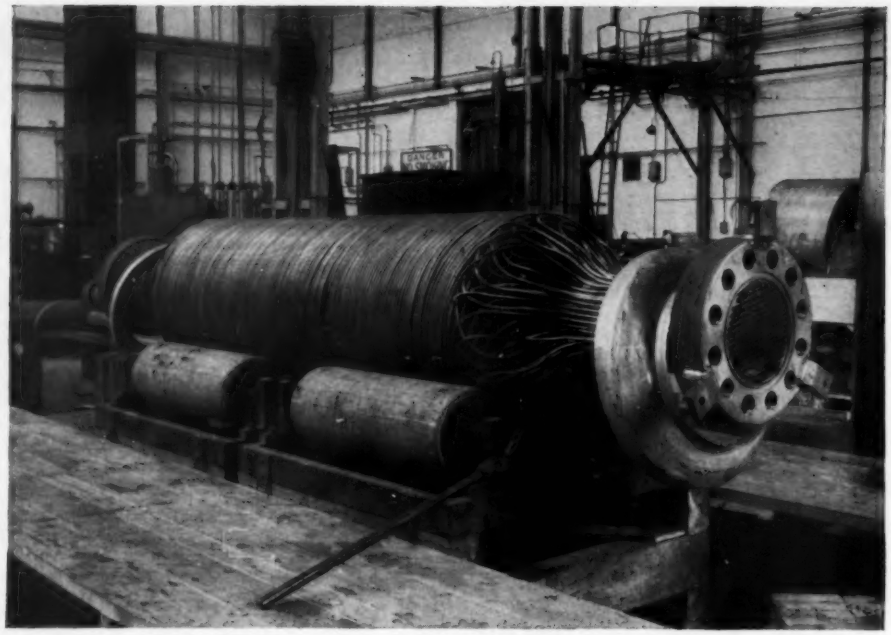


Fig. 5. Tube-nest of cross-flow exchanger based on original Giauque design showing tubes being wound on mandrel.

lower temperature at which vaporisation occurs the impurities have, of course, lower vapour pressures than they had at the temperature at which they were deposited. If the inlet and outlet streams were at the same pressure, complete revaporisation could clearly not occur, but in practice the pressure of the inlet stream is higher than that of the outlet stream and the pressure difference can usually be made sufficient to allow revaporisation. The question is one of design. The efficiency of revaporisation is a function of three variables: (i) the pressure ratio; (ii) the temperature difference; (iii) the slope of the vapour pressure curve of the impurities at the temperature considered. Of these variables, the first is fixed by the refrigeration requirements of the plant, as described in the previous article in this series; the third by Nature, leaving only the temperature difference as a design variable.

Vapour pressure graphs in general are curved in the sense that the slope decreases at lower temperatures. At the lowest levels of temperature, therefore, it often occurs that revaporisation cannot proceed to completion at acceptable values of the temperature difference, and it becomes necessary to influence artificially the temperature difference in the exchanger. This operation is called balancing, which may be effected in four ways: (i) Linde method; (ii) filtration method; (iii) balancing air method; (iv) balancing product method. The effect of the different methods on the temperature distribution in the exchanger is shown in Fig. 6. Note that no balancing method can affect the over-all heat balance: all that is done is to decrease the temperature difference at one point in the exchanger at the expense of increasing it in another.

In the Linde method a small proportion of the air, amounting to 2-4%, is chemically purified and injected directly into the column, by-passing the regenerators completely. It thus reinforces the volume of the returning products, and increases the heat mass of the product stream sufficiently to neutralise the effect of the increase in the specific heat of the feed stream due to compression. Because of the increase in the specific heat of compressed air, one would find, if there were no balancing, that the temperature difference would be higher at the cold end of the regenerator than at the warm end, thus rendering impossible the complete removal of the impurities during a single cycle. The injection of the balancing air balances the heat masses of the two opposing streams and reduces the temperature difference at the cold end, thus securing complete revaporisation and making it possible to run the regenerators indefinitely.

In the filtration method, which is the most widely practised, a part of the stream of air after partial cooling in the regenerator or reversing exchanger is withdrawn so that the heat mass of the remainder is reduced, thereby decreasing the temperature difference at the cold end. The withdrawn stream is scrubbed with liquid air, to precipitate the remaining impurities, which are then removed from the liquid in which they are suspended by filtration. The withdrawn stream after scrubbing is sufficiently pure to be passed into the separating column with the rest of the feed stream (Fig. 7). In Fig. 6 the temperature differences encountered in this method are compared with those found when the Linde method is employed. Note that whereas in the first method the essential low temperature difference at the cold end is obtained by keeping the effective temperature difference constant throughout the exchanger, in the filtration method the temperature difference increases at first as the air is cooled, and decreases later. It is clear, therefore, that the effective mean temperature difference is considerably greater with the filtration method, with correspondingly smaller demands on expensive heat transfer equipment.

Similar considerations apply to the other two balancing methods. In the balancing air method, which can only be used in conjunction with reversing exchangers, the whole of the feed air is passed through the exchanger and completely purified. A part of this purified air is then passed back through the exchanger in the same direction as the returning products, but through a separate passage which is in thermal contact with the rest of the exchanger. This air stream is withdrawn at a temperature which gives a temperature difference of sufficient magnitude to ensure continuity of revaporisation.

In the balancing product method a part of the returning product stream is withdrawn after partial warming and mixed with the cold product stream entering the cold end of the reversing exchanger. The effect on the heat mass of the streams is sufficient to allow consistent revaporisation.

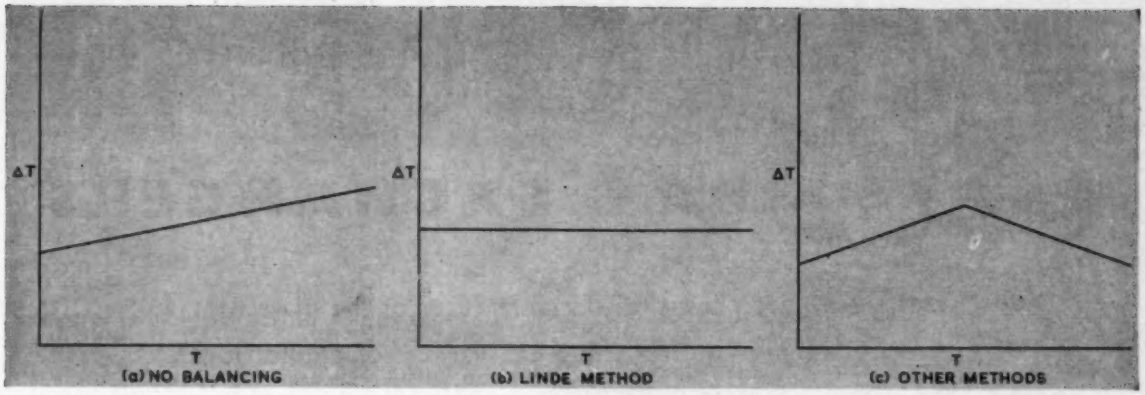


Fig. 6. Effect of balancing upon heat exchanger terminal temperature difference.

Distillation Processes

Distillation processes at low temperatures are subject to the same laws as those at ordinary temperatures, but the plants in which they are carried out show substantial differences in arrangements and in detailed construction. The differences in arrangement are occasioned by the problem of reflux. At ordinary temperatures the problem arises only in a minor degree. The reduction of operating costs can be achieved only by a reduction of reflux ratio and steam and cooling water quantities, but this can only be done at the expense of a longer column. Hence, in normal practice, reflux ratio is decided upon by a balance between capital and operating costs. At low temperatures the same balance is made, but other considerations have to be taken into account. At low temperatures the provision of reflux is no longer a matter of steam and cooling water; condensable gases must be used, which have to be compressed into the apparatus and cooled to the working temperature before they can be admitted to the tubes. The provision of reflux, involving as it does compressors and heat exchangers, is therefore an expensive matter.

Fortunately, the boiling points of the economically important materials which boil below room temperatures are fairly widely spaced. Their relative volatilities are, in fact, usually high enough to allow separation at such low reflux ratios that the latent heat of the gas to be separated is sufficient to provide the reflux for the separation. In some cases this is more than sufficient, and a part of the gas can therefore be expanded in an engine or turbine to provide refrigeration.

Bubble plates are seldom used for distillation at low temperatures, and although this is partly due to the fact that cleaning is seldom required, the main reason is the necessity to reduce the column height to the last degree, and hence the loss of cold from the column to the surroundings. In order to achieve such a reduction in height, it is essential that the trays used shall be of the highest efficiency. In order to ensure this, sieve trays are used on which the liquid is given a directed flow.

In the theoretical plate, in terms of which most distillation calculations are carried out, the vapour bubbles through the liquid (which is assumed to be perfectly mixed) and emerges in equilibrium with it. Since the liquid is perfectly mixed, the vapour therefore emerges from the plate in equilibrium with the liquid leaving. In the plate with directed flow, the vapour bubbles through the liquid and emerges (theoretically) in equilibrium with the liquid at the point of contact. Since the liquid contains, on average, more of the more volatile component than the liquid leaving the plate, it follows that the effect of the plate is greater than that of a theoretical plate.

It also follows, however, that since the liquid has a longer path on the plate, its hydraulic gradient will be greater. And since, in order to save height, the plate spacing is reduced as much as possible, the hydraulic resistance of the plate assumes an importance greater than that in normal columns if flooding is to be avoided. For these and other reasons, the perforated plate is used in preference to the bubble cap.

(In the final article in this series the techniques discussed so far will be illustrated with reference to various commercially important circuits.)

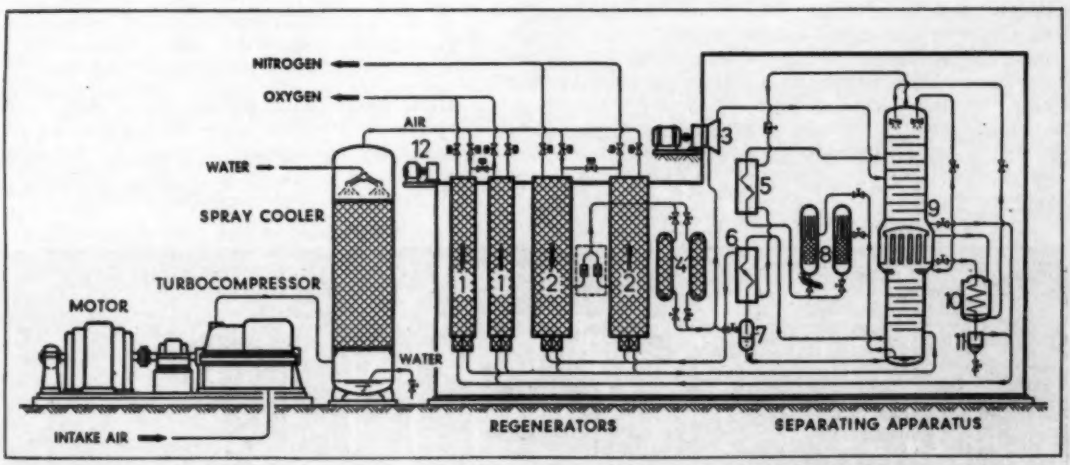


Fig. 7. A Linde-Frankl plant with regenerators. 1-2 Regenerators, 3 Turbine, 4 Adsorbers, 5-7 Exchangers, 8 Filter-adsorbers, 9 Distillation column, 10 Auxiliary condenser, 11 Adsorber, 12 Switching machine.

PLATE HEAT EXCHANGERS

This article describes the special features of the plate heat exchanger and indicates the great variety of applications of which it is capable.

by D. V. PARKER, B.Sc., A.C.G.I.

HEAT exchangers are often a major piece of equipment in a process plant, and generally the practice will be to employ the conventional shell-and-tube-type of exchanger. In some industries, however, particularly the Food and Beverage industries, the plate heat exchanger is widely used. Well-known applications include the pasteurising of milk, the cooling of beer and the chilling of mineral waters.

One of the reasons for their restricted use in the chemical industry has been the limitation, imposed by the mechanical design, to fairly low temperatures and pressures. Recent improvements have made possible its application to higher pressure and temperature duties, with the result that the range of usefulness to the chemical industry has been considerably extended.

The history of the plate exchanger is uncertain. One of the earliest descriptions is that of a German patent dating back to the late nineteenth century. Despite this, little use seems to have been made of the design in the United Kingdom until the early twenties of the present century when the APV Co. Ltd. marketed an exchanger resembling the original German patent and similar in appearance to the plate and frame filter press (Fig. 2).

The plate exchanger (other than the "Rosenblad") is in essence a number of closely spaced plates clamped together and so ported and jointed that the fluids flow on different sides of a given plate. The plates themselves have frequently a corrugated or dimpled surface to promote turbulence and hence high heat transfer rates at comparatively low velocities. It is a design of heat exchanger which allows a variety of flow arrangements and passes to be made at will in a single construction, a feature not shared with any other type of exchanger.

Table I. Comparison of Pressure Drop and Heat Transfer Characteristics of High Turbulence Plate and Tube Surfaces

Type of heat transfer surface	Velocity (ft./sec.)	Pressure drop for unit length of exchanger surface (psi/ft)	Film coefficient of heat transfer (BTU/hr ft² °F)
Tube (diam. 0.23 in.)	1	0.016	350
Tube (diam. 0.23 in.)	3.5	0.10	1000
Plate	1	0.08	1000

Table II. Comparison of Plate Heat Exchanger with Baffled Shell-and-Tube Exchangers when used for a similar duty

The example chosen is that of heating 4000 gph water from 60° to 140°F by means of water which is cooled from 150° to 70°F for a pressure drop of 10 psi.

Type of Exchanger	Overall coefficient (BTU/hr ft² °F)	Individual film coefficients (BTU/hr ft² °F)		Total surface (ft²)
		Inner surface	Outer surface	
Plate	430	915	915	765
Baffled shell-and-tube: (20 bwg tubes)				
½ in. o.d.	283	834	559	1130
¾ in. o.d.	266	751	510	1200
1 in. o.d.	260	698	487	1230

Heat transfer data, particularly on film coefficients, is very scanty. However since the contours of plates vary considerably from maker to maker no one equation will meet all cases.

In the general Sieder and Tate equation

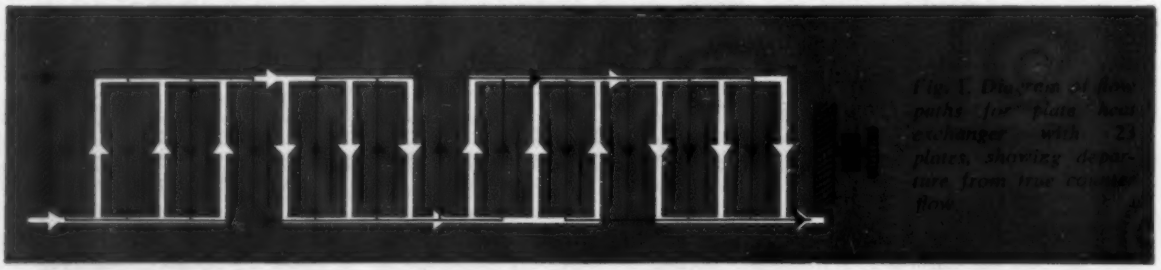


Fig. 1. Diagram of flow paths for plate heat exchanger with 23 plates, showing departure from true counter flow

$$\frac{hD}{k} = K.\ Re^{x}\ Pr^{.33}\left(\frac{\mu}{\mu_s}\right)^{.14}$$

according to the construction of the plate, K may vary between .108 and .012 and x between .8 and .95.

The data given by Goodman[2] may be represented approximately by the equation

$$\frac{hD_e}{k} = .014\left(\frac{DG}{\mu}\right)^{.85}\left(\frac{c\mu}{k}\right)^{.33}\left(\frac{\mu}{\mu_s}\right)^{.14}$$

See p. 147 for list of symbols.

Comparison with other Types of Heat Exchanger

It is characteristic of this kind of exchanger that turbulence is induced at low values of Reynolds number. With some plates turbulent flow may occur at Reynolds number below 200. In most cases, particularly where the values K & x in the above equation are high, the film coefficient for heat transfer are higher than those obtained with tubes for the same value of Reynolds number. At the same time, the pressure loss will be less with the plate than for the tube for the same coefficient. This is illustrated in Table I. The film coefficient for the above plate may be approximated by

$$\frac{hD_e}{k} = .08\ Re^{.85}\ Pr^{.33}\left(\frac{\mu}{\mu_s}\right)^{.14}$$

Plates, however, will vary in their characteristics and the above is not necessarily typical, since some will show both lower heat transfer coefficient and pressure losses for the same Reynolds number.

Tubular types and plate types may be compared on the basis of exchangers designed for the same duty. For this purpose the following duty has been chosen:—

Heating Fluid 4000 g.p.h. water at 150°F cooled to 70°F.

Heated Fluid 4000 g.p.h. water at 60°F heated to 140°F.

Pressure drop both fluids 10 psi.

The results are summarised in Table II, which gives data from a commercial quotation[3] together with results of design calculations for baffled shell-and-tube exchangers employing different sizes of tube. The tube used in the design was square pitch with ¼ in. clearance arrangement.

The type of plate considered in Table II is not strictly comparable to that of Table I, and has a lower pressure loss on an equivalent heat transfer basis. Nevertheless the figures given, particularly those of column 5, demonstrate the superiority of the plate type for the given application.

A further series of comparisons is given in Table III based upon volume power and heat transfer characteristics. In this instance the plate exchanger shows a slight superiority over the tubular exchanger in (heat transfer) x (power/surface) ratio, but in other respects, such as volume and surface per unit volume, it is shown to be distinctly superior.

Since the plate exchanger is a type of compact exchanger it is of interest to compare its various properties with some

Table III. Comparison of Plate and Shell-and-Tube Exchangers

Type of Exchanger	Film conductance x Power / Surface x 10		Volume of heat exchange surface (ft^3)	Surface / Volume (ft^2/ft^3)
	Inside film	Outside film		
Plate	1.5	1.5	8	93
Tubular (20 bwg tubes)				
¼ in. o.d.	1.49	1.39	37.0	30.5
½ in. o.d.	1.61	1.32	48.0	25
¾ in. o.d.	1.62	1.29	60	20.4

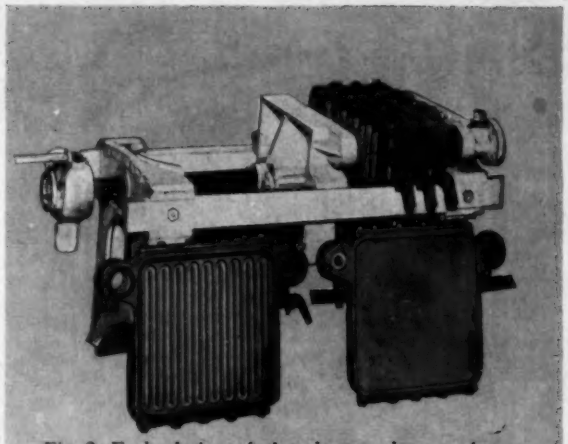


Fig. 2. Early design of plate heat exchanger showing resemblance to filter press. (Photo: APV Co. Ltd.)

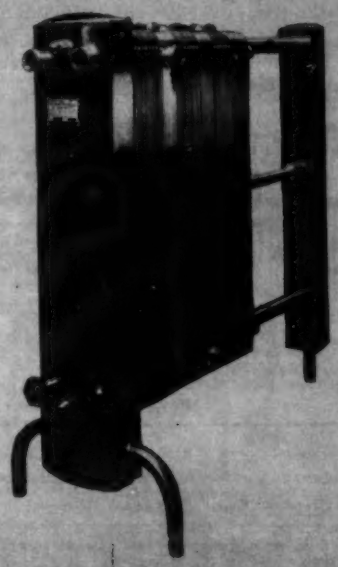


Fig. 3. Example of multipass plate heat exchanger construction. (Photo: Creamery Package Ltd.)

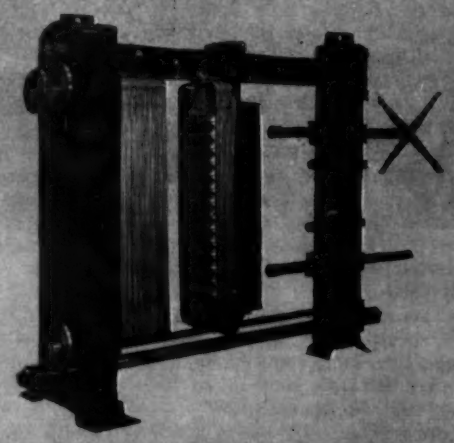


Fig. 4. A typical high pressure design of exchanger. (Photo: APV Co. Ltd.)

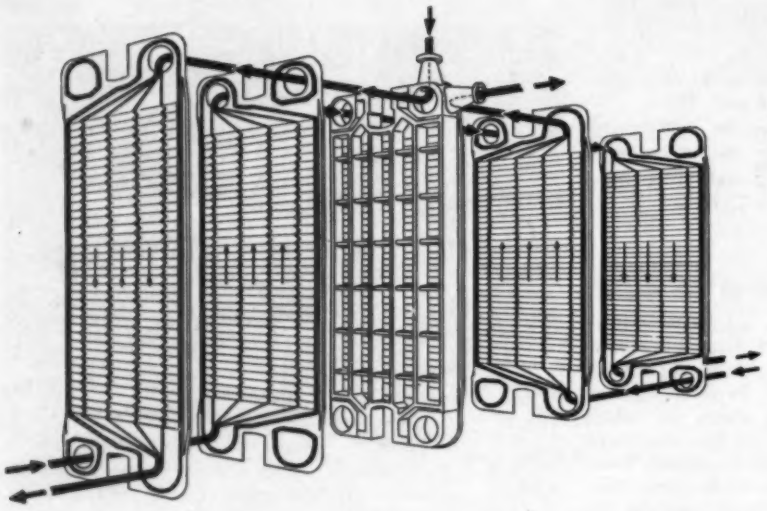


Fig. 5. Plate arrangement showing the function of the connection plate. (Photo: Alfa-Laval Co. Ltd.)

extended types as those described by Kays, London and Johnson.[4] These include finned flat tubes and pin fins. The comparison in Table IV is made using the conversion method described by McAdams.[5]

Table IV. Comparison of Heat Transfer Properties of Plate Heat Exchanger with Compact Extended Surface Types and Tubes for Equal Power/Surface and Power/Volume Basis

Type of surface	Surface/unit volume (B)	Film coefficient x B for equal power/volume value (pin fins = 1)	Film coefficient for equal value of power/area
In line pin fins	244	1.00	1.00
Fin flat tubes[4]	305	0.54	0.53
Inner surface of tubes	208	0.40	0.520
Plate	245	0.63	0.550

Table V. Surface Area Characteristics of Typical Plate Exchanger Designs

Type (APV designation)	Projected Area (ft^2)	Developed area (ft^2)
HT	1.00	1.35
HX	1.45	1.81
HM	2.88	3.73
HF	3.85	4.60

The plate exchanger is thus shown to be comparable with some compact and surface types, although not equal to the best types of compact surface on the basis considered. It should be mentioned, however, that many compact and extended surface types are applied mainly to gas heat transfer problems. Since this field is one for which the plate exchanger is seldom used, the comparison is not an entirely valid one.

The data given in Tables I-IV serves to illustrate some of the special heat transfer advantages of the plate exchanger over more conventional heat transfer equipment. These may be briefly summarised:

1. Greater compactness;
2. Low weight;
3. Higher heat transfer rates without increased pressure loss.

Mechanical Features of Plate Heat Exchangers

(*a*) *Size of Plates and Spacing:* Table V (after Coulson and Richardson[6]) gives an idea of the main dimensions of plates. A common size is 15 in. x 30 in. x 20 in. swg thickness. The plate spacing varies from design to design, a rough range being 0.05-0.125 in.

A factor for which allowance must often be made by the designer is the tendency of plates, despite the stiffening imparted by their contours, to deflect under the action of fluids at different pressures. The result of such deflections is to reduce or increase the cross sectional area for flow depending upon whether the fluid is at the lower or higher pressure. Hence, failure to allow for such deflections may result in an unsatisfactory design from the point of view of the pressure drop involved.

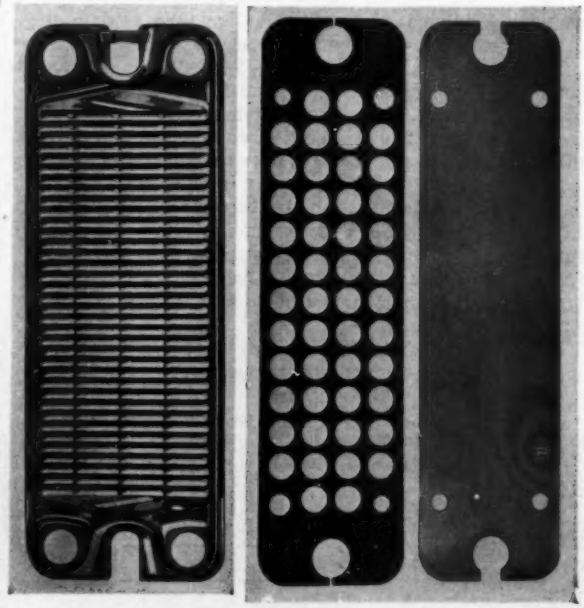


Fig. 6. Examples of plate construction: (left) A plate manufactured by Alfa-Laval Co. Ltd.; (right) A Creamery Package plate and separate seal.

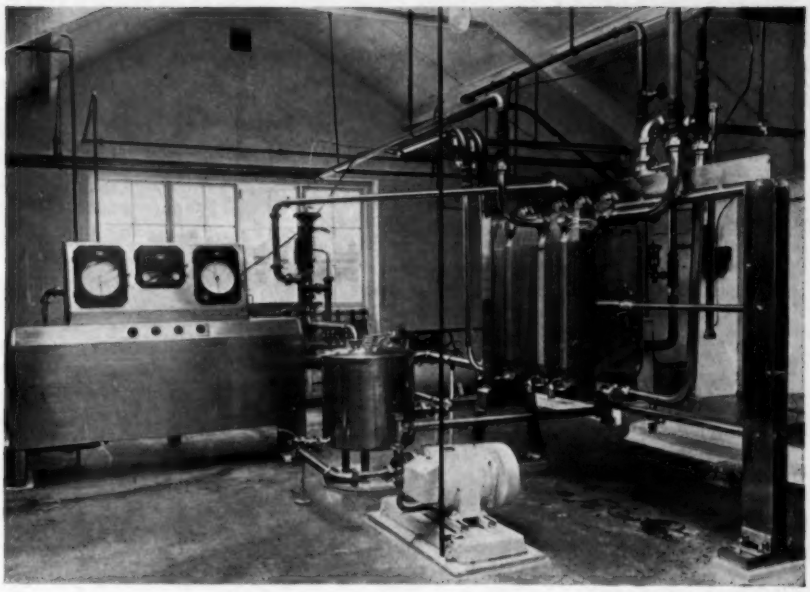
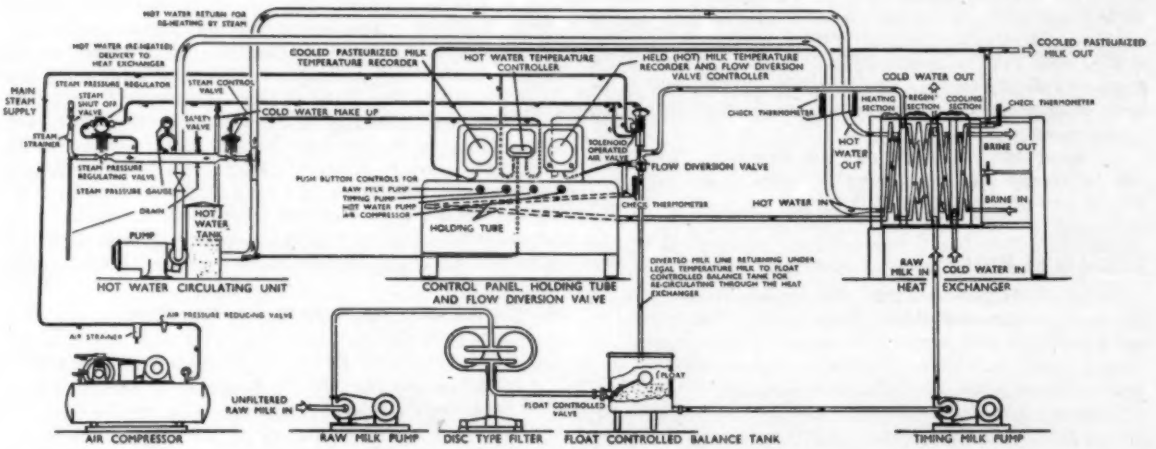


Fig. 7. Diagram below and view right of milk heat treatment plant. (Photo: Clarke-Built Ltd.)



Factors such as this are of great importance when the duty of a particular exchanger is altered from that for which originally it was designed.

(*b*) *Plate Arrangement*[6]*:* This subject has a great bearing upon the success of the basic design. In steam heating it is customary to employ one pass only on the steam side, steam entering at the top of the assembly and flowing downwards with the condensate across the plate. When the heated fluid is heat-sensitive (e.g. milk) it must be kept at a high velocity when near the critical temperature. In practice this is done by reducing the number of plates per pass up to the final pass. Such an effect would be brought about by employing, for example, a 10/7/5 arrangement in the sequence given to make the velocity in the last pass double that in the first.

When one of the fluids has to be drained the inlet connections must be arranged to permit this operation. Normally not more than two passes are used when drainage is required. It is difficult to obtain complete draining on account of the high surface/volume ratio (40 : 1 and over).

Air locking is a further consideration which occasionally requires attention especially when the flow is in the streamline region. In some exchangers this is overcome by employing dimples instead of grooves to give the required turbulence, the intention being not to hinder the flow of whatever air is present thereby preventing its accumulation at the heat transfer surfaces.

Connecting Plates: A typical plate is shown in Fig. 5 Their purpose is to distribute the various fluids to their proper sections of an exchanger. They are used where it is desired to heat or cool several fluids simultaneously and result in an assembly which combines several exchangers in a single unit. The connecting plate confers economic advantages upon this type of exchanger not shared with other types. These are discussed in the section on economics.

Gasket Materials: The gasket limits the use of this type of exchanger to temperatures below 200°C and pressures below about 200 psig. Naturally, selection of suitable gasket materials to withstand the action of a variety of materials is a problem requiring careful attention.

In many designs the gasket is set in a groove around the edge of a plate and is bonded to it by a cement, which along with the gasket must be able to resist the action of the fluids being handled. As mentioned earlier, the presence to the groove serves to strengthen the plate and also reduces the area of the gasket in contact with the fluid. This is very useful when the fluids being handled are.

through absence of an entirely suitable gasket material, likely to attack the gasket.

Different methods have been employed from time to time to solve the gasket problem. An early APV design avoided gaskets and used machined faces. A more modern design (Fig. 6b) employs a detachable gasket which does not require cementing. This has cut-outs to promote turbulence and is used with a flat plate. The design appears to have a disadvantage in that the gasket surface available for attack is considerable when compared with other designs (Fig. 6a).

Materials of Construction: Aluminium, various austenitic stainless steels, and copper are currently used. End and other pieces, which do not come into contact with the fluids being treated, are constructed of cast iron, or fabricated from mild steel. This avoids the use of expensive materials for the entire exchanger, an advantage which is not always possessed by more conventional exchangers.

General Features: Designs vary according to the method of clamping the plates together. One set of constructions uses the original method of a central screw within a rigid frame (Fig. 2).

In other assemblies (Figs. 3 and 4) the supporting bars carrying the plates are threaded at one end, so that the plates are clamped together by means of nuts at the free end. In all cases the load is taken, after the style of the filter press, by rugged end-pieces.

For an internal pressure of 75 psi the load on the threads of the tightening device are 16 tons for a 3 sq. ft. plate Such considerations prompted some makers to seek ways of distributing the load; thus in one design, now abandoned, there was incorporated a central screw with a number of bolts around the periphery. A modern high-pressure type is shown in Fig. 4.

An advantage of all designs is the ease with which they can be dismantled for cleaning purposes or for extension or addition of connecting plates.

Design of Plate Exchangers

While the procedure may be of interest a detailed account is beyond the scope of this article. Therefore, since the makers (whose equipment varies considerably) have most of the available information on pressure drop and film coefficients, the basic design is best left to them.

One may however indicate the basis of a procedure for evolving a design. By a combination of various expressions dealing with heat transfer, pressure drop and heat load, it is possible to derive an equation for the mass flow for a fluid pressure drop.

$$G = \left(\frac{2\,Kg_0\Delta p}{a\,F_s f(\Delta t)B}\right)^n$$

Trial and error solution of this equation—the $\triangle$t terms have to be consistent with the coefficients calculated from the G values obtained by the equation—gives the cross sectional area of flow and the number of plates per pass for each fluid.

In the course of such a calculation a number of adjustments may have to be made to the temperature term, particularly if the arrangement of flow paths involves a departure from true counterflow. One may find, for example, that 23 plates are required in a particular case and that these have to be arranged so that the one fluid requires three plate spacing per pass and the other four. This would be called a

$$\frac{3/3/3/3}{4/4/4}$$ arrangement.

Such an arrangement requires a departure from true counterflow and correction to the mean temperature difference requires more surface. One might make the design final by adding say four more plates to give a

$$\frac{4/4/3/3}{5/5/4}$$ arrangement.

Economic Aspects of Plate Heat Exchangers

In the case considered previously, the cost of the cheapest tubular exchanger employing mild steel shell-and-tube plates and aluminium bronze tubes would be around £1250, whereas the plate exchanger with stainless steel plates would cost approximately £2400. If the duty required stainless steel to be used for either corrosion resistance or prevention of products contamination the picture would change in favour of the plate exchanger because cost of the tubular equipment would rise to about £3000. In addition, the plate exchanger would have the advantages of accessibility and economy in space and pipe work. It should be noted that tubular exchanger costs vary according to the 0.68 power of the capacity ratio whereas in the case of the plate exchanger the exponent is much closer to unity. This means that for large capacities the tubular exchanger would become relatively lower in first cost but this would usually be for duties outside the range of the normal plate exchanger.

A further point concerns the use for multiple duties. If a given exchanger costs £1700, with plates alone costing £1200, has to be converted to multiple operation, a connecting plate will be used. Assuming the conversion to require double the surface, then the total additional cost with the connecting plate at about £120 would be £1320. This represents a saving of approximately £380. Obviously the addition of further heat transfer sections would bring about even greater economy. With the tubular exchanger the increased capacity would have to be obtained by multiplication of the units and would include much more alteration to pipe work. The possibility of similar economies are, therefore, unlikely to exist with such exchangers.

Applications for Plate Exchangers

The kind of uses to which these exchangers may be put are:—

1. Heating or cooling of one liquid by another, including cooling by indirect refrigeration, e.g. chilled brine.
2. Heating liquids by means of condensing steam.
3. Superheating of liquids prior to evaporation.
4. Cooling effluent by boiler feedwater.
5. Heating oil by engine coolant.
6. Preheating still feed with hot bottoms or condensate.
7. Rapid chilling of fruit juice concentrates.
8. Concentration of heat-sensitive liquids.

In such general applications it is possible to work to quite small temperature differences of the order of 2-4°F. It should be noted, however, that the maximum throughput of liquor is then normally below 5000 gph. Larger throughputs as high as 40,000 gph are possible where small temperature changes are demanded.

The heat transfer performance befits them for many duties formerly assigned to other types. The removal of heat of reaction in combined gas absorption and chemical reaction is an application for which the plate is very suitable. The absorption of nitric oxide is an example of such an application.

The ability to perform satisfactorily with small temperature differences is one reason for their suitability for heat recovery uses. The pulp and paper industry, for example, uses them for heat recovery from lye solutions and from waste water and condensate.

Another field in which the plate scores is where the demand is for highly hygienic conditions of heat transfer.

For this reason the dairy and brewing industries use this type extensively for the treatment of milk (Fig. 7) and beer respectively. It is also becoming more widely used by manufacturers of antibiotics such as penicillin and chloromycetin. Wider recognition of the versatility, excellent heat transfer qualities, and economy where special materials are used in the construction, is likely to lead to many more applications of the plate exchanger for the kind of job to which it is suited.

Summary of Characteristics of Plate Heat Exchangers

This type of exchanger has, therefore, good power per surface ratios, i.e. high heat transfer ratios are obtained without sacrifice of power. They have excellent surface volume relationships and hence are extremely compact. The heat transfer conditions on either side of the plate are known with equal precision, which is a distinct advantage over shell-and-tube exchangers where the conditions of flow at the outer surface of the tubes is always a factor of uncertainty. This advantage makes it possible to avoid the use of large safety factors and, consequently, avoids over-designing an exchanger. Moreover, the design lends itself to duties where a very small temperature difference is available.

The mechanical design allows an assembly to be quickly dismantled for cleaning, thus preventing any serious reduction in heat transfer performance. It is also a simple matter to alter the heat transfer surface and its arrangement for purposes other than those for which the exchanger was designed. It is possible by means of connecting plates to incorporate more than one exchanger within the framework of a single unit.

Finally, through their compactness and ease of draining, the amount of liquid retained is small in comparison with tubular types. This advantage makes them particularly useful for batch operations.

On the debit side, the main disadvantage are their unsuitability for uses at elevated temperatures and pressures, and for applications involving gases. Furthermore, they should not be used where the fluids contain particles of comparable size to the plate spacing.

LIST OF SYMBOLS

a = constant appearing in friction factor equation.
B = correction factor in friction relation.
c = sp. ht. of fluid.
D_e = equivalent diameter.
G = mass flow rate.
K = constant in film coefficient equation.
k = thermal conductivity.
n = exponent.
$\triangle p$ = pressure drop.
$\triangle t$ = temperature drop.
s = subscript referring to surface temperature.
x = exponent of Reynolds No.
μ = viscosity.
ρ = density.
Pr = Prandtl No.
Re = Reynolds No.

REFERENCES

[1] *Fuel Economist*, Sept., 1953.
[2] Coulson, J. M. and Richardson, J. F., "Chemical Engineering" Vol. 1, p. 220-221. Pergamon Press: London, 1954.
[3] Private Communication from George S. Clayton Ltd.
[4] Kays, W. M., London, A. L. and Johnson, D. W., "Gas Turbine Heat Exchangers," American Society of Mechanical Engineers: New York, 1951.
[5] McAdams, W. H. "Heat Transmission," 3rd Edition, McGraw-Hill: New York, 1954.

New Fertiliser Works in Scotland

WHERE only a few years ago the waters of the Firth of Forth swirled against the sea wall, a large fertiliser works is now being built by Scottish Agricultural Industries Ltd., on land reclaimed by Leith Dock Commission. So far 12 acres have been reclaimed, but tipping is still in progress and the ultimate aim under the present scheme is 19 acres. The site is ideally situated, having a deep water berth to the west and a large railway marshalling yard to the south east.

The new factory will produce granular concentrated compound fertilisers on a large scale. The whole project, including reconstruction work at the existing fertiliser works of S.A.I. at nearby Salamander Street, Leith, is expected to cost over £3 million. The number employed on both sites, including technical and other staff, is expected to be about 220.

Unloading Raw Materials

Raw materials—phosphate rock, sulphur, potash, etc.—arriving by ship will be unloaded at the rate of 350 tons per hour by three new dockside grabbing cranes being installed by the Leith Dock Commission. Thereafter the material will travel by conveyor, housed in an overhead gantry, to the main storage building.

This store is one of the main features of the site, being 907 ft. long by 100 ft. wide with a double deck overhead conveyor gantry running the whole length. Here different types of raw materials amounting to 56,000 tons will be stored near where they will subsequently be processed. The building comprises 6-ft high reinforced concrete side walls strengthened by buttresses on which precast ribs stand to form a three-pin arch 41 ft. high at the centre. The half-ribs, each 75 ft. long and weighing six tons, are cast at Newmains, over twenty-five miles away, and brought to Leith, three at a time, on a special lorry. Work is well under way with this building and already two-thirds of the 66 arches are in place.

A maintenance workshop with a floor area of 18,000 sq. ft. is also practically finished. It will house all requirements for repair work including storage for spare parts and office accommodation for workshop staff.

The first process plant—expected to go into production this August—is a Simon-Carves/Monsanto sulphur-burning contact sulphuric acid plant with a rated capacity of 175 tons of acid per day. Waste heat from the combustion of sulphur will be used to produce 17,000 lb./hr. of high pressure steam.

The second main process plant, the building for which is now being erected, will manufacture phosphoric acid from phosphate rock and sulphuric acid by the Prayon reaction process followed by their tray filter in which waste gypsum is extracted from phosphoric acid magma by vacuum filtration.

Ammonium Phosphate Production

The finished fertilisers will be produced in the third process building, to which will be delivered the phosphoric acid and various other raw materials required for the manufacture of concentrated fertilisers incorporating ammonium phosphate. The compounding and granulation plant has been designed by Dorr-Oliver Inc., Stamford, U.S.A., and is being constructed by Simon-Carves Ltd.

Fertilisers from the new factory will be sent to various S.A.I. centres in Scotland. The main distribution for the Leith area will take place from the existing S.A.I. works in Salamander Street. Old plants and buildings at these works have been demolished to make way for a new compounds store of 40,000 tons capacity and high speed bagging plant.

CENTRIFUGAL FILTERS IN THE

by M. E. O'KEEFE TROWBRIDGE, B.Sc., A.C.G.I., A.M.I.Chem.E.

THE centrifugal filter only differs basically from ordinary filters in that the driving force which causes liquid to flow through the filter medium is obtained centrifugally. The centrifugal force may be many times that produced by the acceleration due to gravity and consequently much speedier drainage can be obtained, and a drier cake produced.

In the perforated basket continuous centrifuge, a different mode of action is involved from that in the centrifugal sedimenters which have already been described.* In the centrifugal sedimenter the solids are separated from a continuous liquid phase or phases by a centrifugal settling process, and for separation to be effected, density differential is essential. The perforate basket machine is, however, a true centrifugal filter in that the solids separated from the mother liquor act as a filter bed in most cases. A density differential between the solid phase and the liquid phase is no longer necessary and, in fact, slurries can be handled where the density of the solids is lower than that of the liquid.

Automatic Knife Discharge

In its simplest form the centrifugal filter consists of a perforated basket, lined with a suitable filter medium. This basket rotates on fixed bearings about a horizontal axis. Slurry feed and wash are fed to the basket through suitable nozzles, while discharge of the cake is effected by means of a piston-operated underloader knife (Fig. 1). Almost any degree of complexity of operating cycle can be achieved, but a typical example of the manner in which the machine is used is: (*i*) screen rinse; (*ii*) loading; (*iii*) cake rinse; (*iv*) spin dry; (*v*) unloading.

The cycle (Fig. 1) is controlled by automatic timers, and the time interval for each step may be altered at will by appropriate setting of these timers. Once started, the centrifuge operates continuously, repeating this cycle without further attention. The advantage of this type of perforated-basket centrifuge is that the flexibility of the control mechanism permits almost any desired sequence of operations, and in addition since the timers can be reset at will, it is adaptable for dealing with off-standard material.

The length of the cycle varies according to the nature of the application, but is generally between 30 seconds and 3 minutes. In some special cases, however, cycle times of as long as 20 minutes have been employed. Many variations can be incorporated in the cycle. For example, more than one type of cake rinse can be used. Where necessary, the mother liquor can be kept separate from the rinse liquor or liquors. The spin-dry stage in the cycle can be varied at will to obtain the desired crystal dryness or crystal purity.

In general this type of centrifuge is used for the recovery and dehydration of crystals where the desired product is the solid phase. A characteristic of the knife-discharge perforated-basket centrifuge is that excellent washing can be obtained. It has, however, been successfully used for the separation of microcrystalline and amorphous solids where special considerations such as toxicity, hygiene, vapour hazard, etc., have applied. Another interesting application has been the handling of crystal separation problems at very low temperatures.

Pusher-type Discharge

In the type of centrifugal filter shown in Fig. 4, a different method of discharge is used. The solid material is pushed across the basket, the front of which is open, by

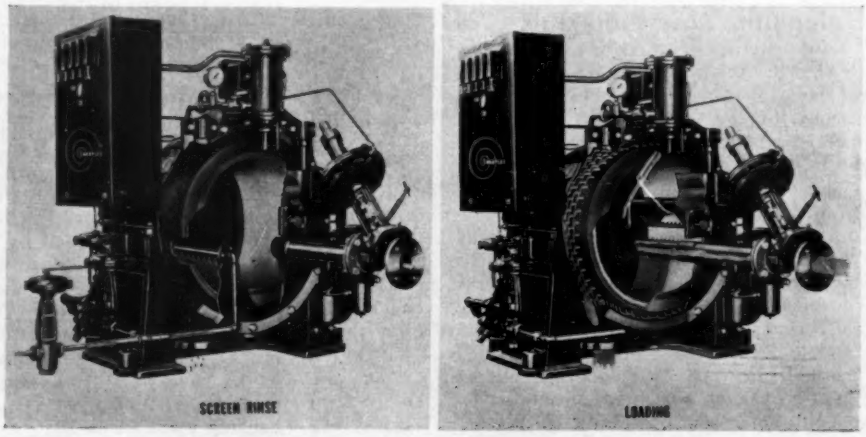


Fig. 1. *The complete operating cycle of the automatic knife discharge perforated basket centrifuge.*

means of a reciprocating piston, which has a frequency of 30-70 pushes per minute.

The construction of the machine is relatively simple. The feed enters by an inlet pipe which ends at a conical distributor, at the centre of the piston. This distributor accelerates the solids to the speed of the screen, thus avoiding sudden impact. The reciprocation of the piston continuously pushes the crystals along, and out of the basket, making way for the continuous feed of slurry.

Washing can be carried out during the passage of the crystals across the basket. After dehydration the crystals are discharged. By means of baffles in the casing, the mother liquor and wash liquor may be kept separate, although the degree of separation cannot be as complete as with an automatic knife-type machine fitted with a diversion valve. For many operations, however, this is not a disadvantage.

Since the solids remain in the basket for only a short time—in some applications as little as 30 seconds—rapid drainage is necessary. This involves a large filter area per unit output, and a very open type medium must be used. A slotted screen basket is, therefore, usually selected, since this also has the advantage of a minimum frictional resistance. Models of pusher-type centrifuges are available in diameters of 230 mm up to 1,200 mm, corresponding to output rates of 200-800 lb/hr up to 30 ton/hr.

The basket, which is generally constructed of stainless steel, may be made in steps, in which case the pusher mechanism is in the form of a piston, and several annular rams. The steps are of increasing diameter, and as the crystals are pushed along the basket they fall from one screen to the next. It is therefore undesirable to use machines of this type for fragile crystals. Solids, which have a tendency to agglomerate, thus preventing successful washing, may be handled successfully with a patented device, comprising conically shaped disintegrating sheets, which act to maintain a permeable cake.

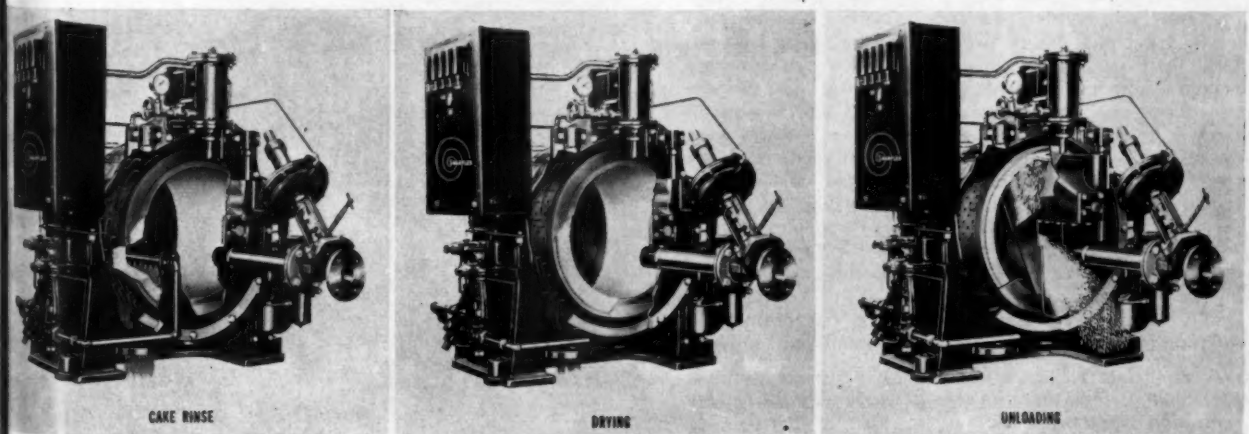
Scroll Discharge Machine

Scroll discharge may also be used on centrifugal filters, which then resemble solid-bowl scroll-discharge sedimentors described in the last issue,* with the exception that the basket is perforated (Fig. 3). While the normal type has a conical bowl, variations are made with a steep conical bowl and with a cylindrical bowl. Units are available ranging from diameters of 230 mm up to 480 mm. The operation is similar to the pusher-type as regards the feed and distributing device, but in the scroll discharge unit the solids are conveyed by means of a screw conveyor. The material in the bowl is thus continually being subjected to a turning and tumbling action.

Perforated screens are generally used with this type of centrifuge, although for the cylindrical bowl version slotted screens may also be used. For certain applications washing may be carried out, although it is not possible to separate the mother liquor and the wash liquor very satisfactorily. The perforated-basket scroll-discharge centrifuge is useful for some types of materials where the tumbling action may help dehydration, although it is reported that crystal breakage is more severe than with, for example, the pusher centrifuge.

Self-discharging Crystal Centrifuge

An interesting new development which has a limited



QUESTIONNAIRE FOR CENTRIFUGE USERS

Liquid-Solid Separation, or Solids Classification

Solid Phase

1. What is the chemical composition of the solid phase?
2. What is the typical size analysis of the solid phase?
3. What is the true density of the solids?
4. If solids are crystals, are they easily fractured?
5. What amount of solid fines is permissible or desired in the effluent mother liquor?
6. Should the solids be washed to displace or neutralise adhering mother liquor? If so, what should be used as a washing medium? At what temperature? How much washing medium can be used?
7. If classification of the solids according to particle size is required, what cut-points are required? What degree of overlap is permissible?
8. What solvent (for the solids) can be used for a screen rinse? How much can be tolerated in the product? Should it be segregated from the effluent mother liquor or from the cake rinse liquor or from both?
9. To what purity must the solids be washed?
10. What is considered to be the maximum free moisture content permissible for the solids as discharged? What tests are to be used to determine free moisture and purity?
11. What disposition will be made of the centrifuged solids, e.g., Heat dried for storage or packaging; melted or dissolved for further processing?
12. What is the maximum quantity of solids to be handled?
13. How is product made at moment and what are objections to present method?

Mother Liquor

1. What is the chemical composition of the mother liquor?
2. What materials of construction are suitable for use in contact with the liquor?
3. What disposition will be made of separated mother liquor, e.g., Discarded; recycled through crystalliser or evaporator?
4. Is it desirable to segregate the wash liquor from the effluent mother liquor? How complete must the segregation be?
5. Does the nature of the mother liquor or other surrounding conditions make it necessary or desirable to handle this material in a vapour-tight machine?
6. Is flame-proof electrical equipment required?

Feed Slurry

1. What is the maximum, minimum and normal concentration of crystals in the feed slurry?
2. Can the concentration of crystals be increased by settling or otherwise? If so to what extent?
3. Within what limits will the concentration of crystals in the feed slurry be controlled?
4. What is the temperature of the slurry at the point of separation?
5. What insoluble impurities are present; give quantity and particle size, e.g., Sand, silica, tramp iron?
6. What is the density of the slurry?
7. What type of crystalliser or evaporator is used?
8. What is the general nature of the process in which the slurry is obtained?
9. A flow sheet and description of the process by which the slurry is obtained will be helpful.

Liquid-Liquid Separation

1. What is the chemical composition of the heavy phase and of the light phase, and in what proportion are they present?
2. What quantity has to be handled per hour?
3. What are the densities of the liquids?
4. What are the viscosities of the liquids
5. What is permissible temperature range for separation?
6. Is the composition of the emulsion constant, and if not to what extent does it vary?
7. Can separation be effected by gravity? If so, to what extent, and how long does it take?
8. What amount of the light phase liquid can be tolerated in the heavy phase, and vice versa?
9. Once again a flow sheet of the process by which the feed material is produced is most helpful.

but useful range of application as a filtration device is the self-discharging crystal centrifuge. It is, in effect, a shallow bowl of roughly conical section, with one or more narrow circumferential drainage screens (Fig. 2). A very thick crystal magma is fed to the centre of the bowl, and proceeds radially outwards under its own centrifugal force. The liquid present drains away to the walls, while the solids ride over the polished surfaces. At the circumferential screen the liquid drains away, whilst the solids pass on. More than one stage of screen may be used and a washing section can be incorporated. Since the crystals pass through the wash zone in a dynamic bed each discrete crystal receives its quota of wash water, and very thorough washing results. As the washed and dehydrated solids reach the periphery of the bowl they are discharged by their own centrifugal force and are directed by vanes out of the discharge chute. In this way crystal breakage is minimised.

A characteristic of the machine is the fact that very little solid is in the bowl at any moment, and in consequence an amazingly low specific power consumption results for a given degree of dryness. For example, a machine for dehydrating 2 tons/hr of ammonium sulphate

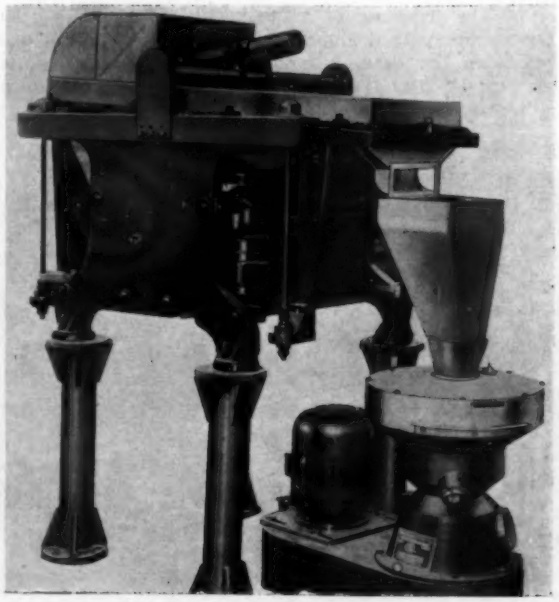


Fig. 2. The self-discharging crystal centrifuge with preconcentration vibrating screen.

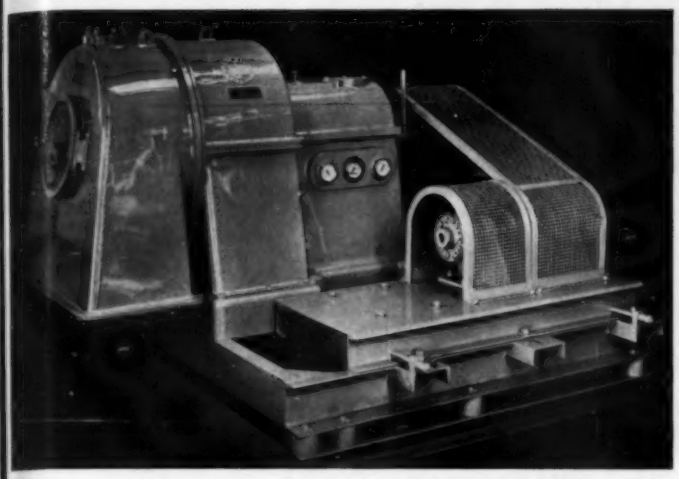


Fig. 3 (above). A perforated basket scroll discharge centrifuge.

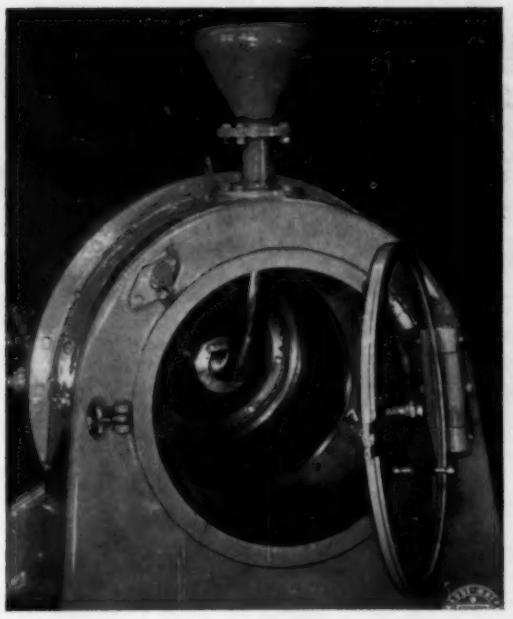


Fig. 4 (right). Pusher-type centrifuge showing the piston and slotted type screen.

requires only a 5 h.p. motor. This moreover means that only very light foundations are required for the centrifuge.

The application of the machine is, however, limited to relatively coarse crystals, say 95% greater than 40 mesh. In addition, a very thick slurry must be fed to the machine. This represents a new and promising development in centrifugal techniques.

State the Problem

In this article and the previous one,* the various types of centrifugal separating equipment commercially available have been reviewed and the types of separation problems indicated according to a broad classification. Before a decision can be made, either by the engineer himself or by a specialist, on the particular type of equipment best suited to a given problem, as much information as possible regarding the applications should be obtained. Only when all the appropriate questions listed on the opposite page have been answered, is it possible to make a satisfactory recommendation.

Acknowledgments

The author's thanks are due to the Alfa-Laval Co. Ltd., Krauss-Maffei-Imperial G.M.B.H. & Co., and Sharples Centrifuges Ltd., for their assistance and information provided for the preparation of this article.

* "A Guide to the Selection of Continuous Centrifuges," *British Chemical Engineering*, June, 1956, pages 68-72.

Figs. 3 and 4 are by courtesy of Krauss-Maffei-Imperial G.M.B.H. & Co. All others by courtesy of Sharples Centrifuges Ltd.

The Production Exhibition

THE exhibition was devoted mainly to the human element and to methods of achieving higher productivity such as employment of instruments for control of product quality, precision casting, work study and so on. The impact of such an exhibition upon the chemical industry particularly that section manufacturing chemicals in large quantities would be expected to be somewhat less than upon the engineering industry. Nevertheless there were in this exhibition a number of items of interest to chemical engineers.

Of most interest perhaps to the chemical engineering fraternity was the exhibition of the West Ham College of Technology which was designed to show the approach of the college to the teaching of chemical engineering. The fields of size reduction and size separation were chosen to illustrate this approach, the particular example selected being a pilot plant investigation of a fine grinding problem carried out to provide data for a large-scale production plant. A punched card computer was provided for analysis of the pilot plant data.

Two stands, those of the D.S.I.R. and the British Iron and Steel Federation, showed models of the continuous steel casting process developed by B.I.S.R.A. The displays were opportune—as the process is one which is able to reduce scrap from discarded ends to a minimum—a feature of especial value where production of high alloy steel billets is concerned. The process is also reckoned to give savings in fuel and plant.

Sondes Place Research Institute demonstrated an extremely compact and transportable steam engine/boiler unit of unusual design. The boiler heating surface consisted of a finned cylinder and was designed to use combustible waste material such as old rags, straw, etc., as fuel. The unit is intended as a cheap source of power for undeveloped areas. A further exhibit by this Institute was of a pilot plant for the manufacture of an improved transparent resin derived from allyl alcohol and methylmethacrylate scrap. The allylmethacrylate polymerisation is controlled by a novel but undisclosed method. Finally a word of praise for the Imperial Chemical Industry's stand which abounded in good ideas all of which were admirably presented.

TANTALUM—ITS MANUFACTURE AND CHEMICAL USES

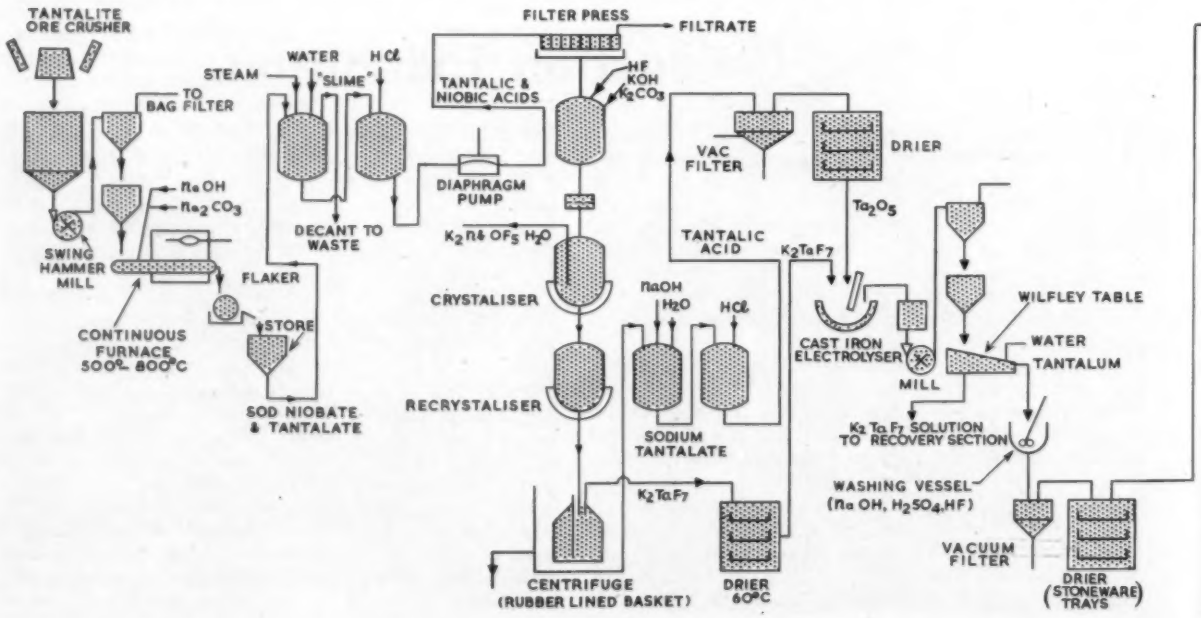
Tantalum is inert to a long list of chemicals, including such acids as hydrochloric, nitric and aqua regia. In this article the various methods of preparing the metal are described as are some of its applications for the manufacture of chemical equipment.

by G. L. MILLER, Ph.D., A.R.I.C., M.I.Chem.E.

THE outstanding property of tantalum is its resistance to attack by many corrosive chemicals; in fact, the metal is virtually acid-proof. The principal restriction to a more extensive use of tantalum is price, but despite the high price its properties are such that in many applications it is more economical to employ it than cheaper alternatives. Immunity to chemical attack combined with high mechanical strength and good thermal conductivity make tantalum particularly suitable for many applications in the chemical industry.

Its good thermal conductivity is enhanced by the absence of corrosion deposits which ensure that tantalum apparatus can be operated continuously and with undiminished efficiency. A further advantage of the use of tantalum is that its mechanical and working properties are such that very thin sections can be produced which makes it possible to obtain excellent heat transfer. The foregoing properties explain the reason for the application of tantalum as a material for heat transfer units handling corrosive liquors or vapours. These advantages, combined with a very good coefficient of wetting, ensure the most economical use of this expensive metal; thus one finds, for example, that one square foot of tantalum is equivalent in heat transference to 18 square feet of lead, and for equivalent steam pressures the rate of heat transfer through tantalum is approximately 10 times as great as that through glass and 20 times as great as that through stoneware.

Probably the most widely known use of tantalum in heat transfer units is its employment as the material of construction in absorption systems for hydrochloric acid; here



water-cooled tantalum surfaces are used to remove the heat of absorption. Many such units are in operation in the United States.

Tantalum finds many other applications in the chemical industry such as bayonet heaters, cooling-coils, diaphragms, venturi, nozzles, etc. On the Continent tantalum is still employed in the form of spinnerettes which combine resistance to corrosion with resistance to wear, a property obtained by hardening the surface by controlled oxidation.

In most cases, particularly in the chemical industry, the use of tantalum is restricted to special applications because of its high cost. The reasons for this is the complicated and expensive operations entailed in its production together with the cost of the tantalum bearing minerals.

Processing of Tantalum Minerals

Tantalum is never found free in nature, and its minerals contain many other elements such as calcium, the rare earths, manganese, iron, tin, tungsten, sodium, niobium and titanium. The last two—particularly niobium—are the most difficult to separate, and it is an advantage to start with a mineral that is as low as possible in these impurities. The type of commercial concentrate that is most suitable for processing is high grade tantalite which may contain about 70% Ta_2O_5, 5% Nb_2O_5, 3% TiO_2 and 2% SnO_2.

The first step in the processing is to "open-up" the ore to render it amenable to further treatment. There are several alternative processes for this step:

(a) fusion with alkaline fluxes; NaOH, KOH, carbonates, etc.

(b) fusion with acid fluxes, e.g. $KHSO_4$, Na_2SO_4-H_2SO_4, etc.

(c) direct solution in hydrofluoric acid.

(d) chlorination with or without carbon.

(e) smelting to crude alloy followed by acid solution.

The only processes which are known to have been operated on a commercial scale are fusion with alkalis and solution in hydrofluoric acid. A brief description is given below of the procedure for these two methods.

Alkali Fusion Method

The usual alkali employed is a mixture containing 9 parts by weight of NaOH and 1 part of Na_2CO_3. The mixture is fused in a steel crucible and the temperature raised to about 500°C at which point the finely ground ore is added. The reaction which takes place is vigorous and it is necessary to add the ore gradually in order to maintain control. When the reaction is complete the product is poured out of the crucibles and allowed to solidify before leaching with water to remove the excess of alkali, silica, and any tungsten which may be present. The sodium tantalate and niobate are insoluble in the alkaline solution, but washing must not be continued too far otherwise these salts tend to dissolve. The insoluble residue, in the form of a "slime," is fed to a boiling solution of 1 : 1 hydrochloric acid and water, when the sodium salts are decomposed and most of the impurities such as iron and manganese pass into solution. The earth acids are washed with hot water acidified with hydrochloric acid and the final washing is made with a dilute ammonium chloride solution in order to avoid peptisation. The earth acids are finally filtered and the wet cake dissolved in hydrofluoric acid solution.

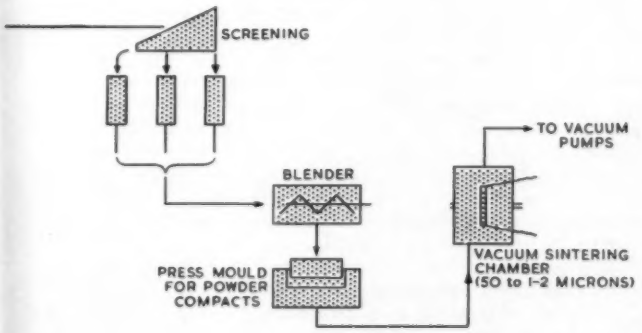


Fig. 1. This flow diagram illustrates the complexity of a typical manufacturing process for tantalum ingots. Note that there are 20 or more distinct unit operations all requiring ancillary mechanical equipment including vacuum pumps, piping and instruments. The use of hydrofluoric and hydrochloric acids calls for the use of special materials of construction. The first costs of such a plant is, therefore, high.

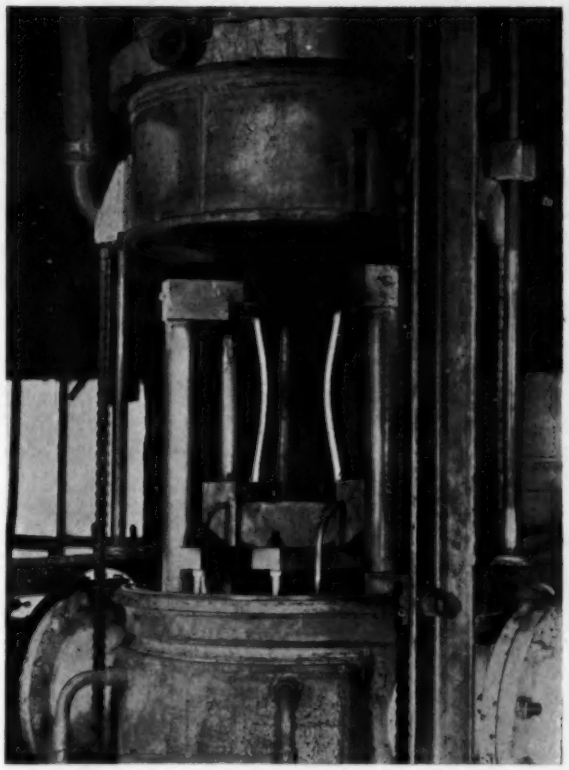


Fig. 2. Vacuum sintering chamber for tantalum ingot manufacture from powder compact. (Photo: Murex Ltd.)

Direct Solution in Hydrofluoric Acid

Direct solution of the ore in hydrofluoric acid is not readily achieved, but it is possible if the ore is ground to a very fine state of sub-division and digested with hot 72% hydrofluoric acid.[1] This method of operation was employed at Siemens & Halske in Berlin, but it suffers from the disadvantage of handling hot concentrated hydrofluoric acid solution. Furthermore, the fluoride liquors obtained are less pure than those obtained from the alkali fusion method. This results in a less satisfactory recovery of the tantalum. The ore must be boiled for six hours for decom-

position, and it is reckoned that this results in a loss of 25% of the hydrofluoric acid. It was found that one acid treatment was not sufficient to decompose all of the ore, and it was therefore necessary to decant the first lot of acid liquor and re-treat the residues with fresh acid. The fluoride solution of tantalum and niobium was then in the same state as that obtained by hydrofluoric acid solution of the alkali fusion product and ready to proceed to the next stage, which is the separation of the tantalum and niobium. The titanium is also present in the liquor and its separation from the tantalum is equally as important.

The separation of niobium from tantalum and, incidentally, from the titanium also, is usually performed by what is known as the Marignac process, which depends on the difference in solubilities of potassium tantalum fluoride and potassium niobium oxyfluoride. The niobium salt formed under the conditions employed is the double oxyfluoride (K_2NbOF_5) and not the normal double fluoride (K_2NbF_7). In practice, sufficient potassium fluoride is added to convert the tantalum, niobium and titanium fluorides to double fluorides. Usually it is preferable to introduce the potassium as potassium carbonate which reacts with some of the excess hydrofluoric acid and may be used to control the acidity. The less soluble tantalum salt, K_2TaF_7 (solubility: 1 part in 200 parts dilute hydrofluoric salt, at 15°C) separates leaving the more soluble niobium salt, K_2NbOF_5 (solubility: 1 part in 12-13 parts dilute hydrofluoric acid at 15°C) in solution with the titanium salt. It is usual to recrystallise the potassium tantalum fluoride by dissolving it in hot 1% hydrofluoric acid solution, which is then cooled to yield a tantalum salt substantially free from niobium and titanium.

The tantalum salt is filtered and dried carefully at about 60°C and the fine crystalline product is then ready for reduction to metal.

The problem of handling the fused caustic needs to be mentioned, and more important still is the problem of handling concentrated boiling hydrofluoric acid. During the digestion of the ore with the fused caustic, considerable experience is necessary to avoid a "boil-over," which would result in loss of valuable material and possibly injury to the operators. Even under the best conditions a caustic spray is constantly emitted and can play havoc with most building materials.

Handling Hydrofluoric Acid

When handling hydrofluoric acid, there is always the danger of injury to the operators; even small amounts of acid can cause painful injuries. Again, acid-proof tanks, such as rubber and carbon-lined vessels, are expensive and often have a surprisingly short life.

For the storage of hydrofluoric acid of less than 80% strength mild steel tanks are satisfactory; for acid of less than 65% strength, neoprene or lead-lined mild steel tanks are used. The basic requirements necessary for the prevention of accidents when handling hydrofluoric acid[2] are the use of protective clothing, this includes rubber boots and rubber gloves; adequate ventilation for the removal of acid fumes (gas-masks may be provided in special cases); protection of the face (an ointment with a lanoline base is recommended). In addition to these measures emergency showers or clean water-bottles should be provided and a number of eye-wash bottles with clean distilled water or other suitable liquid should be kept in conveniently situated boxes.

Reduction to Metal

Several methods have been proposed for the reduction of tantalum. All of these recover the metal in the form of a powder as none attain the very high temperature required to melt the metal (approx. 3000°C). The methods which Report No. 803.[1] The main features are as follows.

(a) reduction of the double fluoride K_2TaF_7,

(b) electrolysis of a fused bath of K_2TaF_7, KF, KCl and Ta_2O_5,

(c) reduction of tantalum pentachloride with magnesium.

Other methods have been suggested but these are of little importance. The methods used commercially are the sodium reduction and the electrolytic process. The magnesium reduction of the pentachloride in a revived form is of interest and worthy of mention; in 1943 von Zeppelin[3] produced tantalum by heating to reaction temperature a mixture of anhydrous pentachloride, magnesium chips and potassium chloride, in a steel crucible.

Fig. 3. Model of a tantalum condenser with mild steel water jacket. (Photo: Murex Ltd.)

The Sodium Reduction Process

A detailed account of this process can be found in BIOS Report No. 803.[1] The main features are as follows:

The reduction of potassium tantalum fluoride is relatively simple; the difficulty comes when the reduced metal is separated by leaching from the other products of reduction. Steel-pots are used to contain the charge which is prepared by adding alternate layers of fluoride and sodium with a layer of dried sodium chloride at the bottom and top. The pot, or crucible, is sealed with a weighted steel-plate and is not in any sense the bomb which is sometimes indicated in the literature. The reaction is started in one section of the tube by heating the crucible with a gas-ring, and rapidly spreads throughout the whole mass. When the reaction is complete the crucible and its contents are allowed to cool to room-temperature and after filling with methylated spirits, the charge is broken out of the crucible and leached with water until free from fluoride. A final washing with dilute hydrofluoric acid is given and the metal powder drained and air dried at 60°C and is then ready for consolidation. Though the process is comparatively simple, the achievement of satisfactory powder is accomplished only by experienced operators.

Handling Sodium

The handling of the sodium requires special precautions to avoid serious accidents. The sodium should be stored in a dry room without a sprinkler system or water or steam pipes.[4,5] Heat and ventilation should be provided to prevent condensation on the steel containers. Sodium metal should

be handled only by operators wearing loose, dry gloves made of canvas, moleskin, or rubber. The eyes should be protected with goggles. The clothing worn by the operator should be kept dry and should be loose fitting so that it can be discarded rapidly. Burning sodium reacts vigorously with asbestos cloth, which therefore should not be employed as a protective medium.

Water must not be used to extinguish sodium fires as it reacts violently with the metal giving hydrogen which can ignite spontaneously and explode, scattering the burning metal. Carbon dioxide is also not a good extinguishing medium; there is a risk that carbon monoxide will be produced and that this will combine with the sodium to form an explosive carbonyl. The use of hydrocarbons, foam and soda-acid are also not advised. Dry nitrogen is a safe medium to blanket a sodium fire, and dry sodium carbonate (soda ash), dry sodium chloride or dry graphite may be used as extinguishers. Although carbon dioxide is not recommended by the authorities it has been found in practice that it does extinguish fires of sodium up to at least 28 lb. The factor which appears to be important is the rapid cooling effect achieved during the discharge of the carbon dioxide, which rapidly extinguishes the fire even in the presence of methylated spirit.

Table 1. Physical Properties of Tantalum[12]

Atomic weight	180.88
Density, g/c.c.	16.65
Melting point, °C °F	2996 approx.* 5425 approx.
Tensile strength, lb./sq. in. hard drawn wire, or rolled sheet worked annealed	 125,000-170,000 50,000- 75,000
Elongation % unannealed worked annealed	 2-3 25-40
Modulus of elasticity, lb./sq. in.	27,000,000
Brinell hardness sintered bar (18 x 18 mm)	 45-600
Linear coefficient of expansion, per °C	6.6 x 10^{-6} (20-500°C)
Thermal conductivity, cal/sec (sq. cm/cm) °C	0.13 (20-100°C) 0.174 (1430°C) 0.198 (1830°C)
Specific heat, cal/g	0.036 (58°C)†
Electrical resistivity, microhms/cm	15.5 (20°C) 71 (1430°C) 80 (1830°C)

N.B. The figures in the above table, which show the variation of properties with the physical state, i.e. annealed, unannealed, etc., should be accepted with reserve because it is almost impossible to define the exact state of the metal.

*Malter and Langmuir, 1939.
†von Bolton, 1905.

Table 2. Corrosion Resistance of Tantalum[13]

Corrosive Liquid	Temperature °C	Temperature °F	Duration of test	Loss in Weight g/dm² day	Loss in Weight oz./ft² yr.
HCl conc.	19-26	66-79	135 d.	0.0000	0.0000
Muriatic acid	19-26	66-79	135 d.	.0000	.0000
HCl conc.	110	230	5 d.	.0000	.0000
HNO_3 conc.	19-26	66-79	135 d.	.0000	.0000
HNO_3 conc.	86	187	6 d.	.0000	.0000
H_2SO_4 conc.	19-26	66-79	135 d.	.0000	.0000
H_2SO_4 conc.	147	297	90 d.	.00004	.0048
H_2SO_4 conc.	175	347	30 d.	.0014	.167
H_2SO_4 conc.	200	392	30 d.	.0177	2.11
H_2SO_4 conc.	250	482	6 h.	.332	39.6
H_2SO_4 conc.	300	572	3 h.	3.96	473.0
H_2SO_4 conc. + $K_2Cr_2O_7$	19-26	66-79	135 d.	.0000	.0000
H_2SO_4 conc. + $K_2Cr_2O_7$	96	205	90 d.	.00004	.0048
CrO_3—Plating sol.	98	208	90 d.	.00002	.0024
Ferric chloride, conc.	19-26	66-79	135 d.	.0000	.0000
Iodine KI-H_2O-Sat.I_2	19-26	66-79	135 d.	.0000	.0000
Bromine (Lig.) Br_2	19-26	66-79	135 d.	.0000	.0000
H_3PO_4-85%	145	293	90 d.	.00005	.006
H_3PO_4-85%	180-210	356-410	31 d.	.0027	.322
H_2SO_4-fuming-15% SO_3	23	73	2 d.	.0032	.382
H_2SO_4-fuming-15% SO_3	70	158	6 h.	1.06	126.6
H_2SO_4-fuming-15% SO_3	130	266	2 h.	45.6	(340 lb)

Electrolysis from a Fused Bath

The potassium tantalum fluoride produced in the first chemical process is fused in a cast-iron pot, which acts as the cathode, and tantalum pentoxide is added and dissolved in the melt. Using a graphite rod as the anode, the electrolysis is started and as it proceeds the tantalum is deposited as a crystalline metallic powder which is disemminated through the fused salt. At the finish about 15% of the contained tantalum has been converted to metal which is recovered by crushing in a mill fitted with an air separator to recover the heavy metal powder. The latter is further treated on a Wilfley table to separate the metal from the potassium tantalum fluoride. The metal is then treated alternately with dilute sulphuric and dilute caustic potash solution and finally with dilute hydrofluoric acid. The process as described was employed by the Fansteel Metallurgical Company.[6]

An earlier process was developed by Westinghouse[7] to overcome the anode effect. The electrolysis procedure is described as follows: Using a bath composition of 100 parts KCl, 40 parts KF, 25 parts K_2TaF_7 and 6 parts Ta_2O_5 with a graphite crucible serving as anode and with a molybdenum or nickel cathode suspended in the centre of the crucible, the electrolysis is continued until "anode effect" and a sharp rise in voltage indicates that the oxide is used up. The cathode with adhering metal and solidified salt (in about equal proportions) is withdrawn and washed in water to remove the salt. The product is ground and washed with water again, to remove the small amount of insoluble basic tantalum fluoride. The metal was then ground to pass 250 mesh screen, and boiled with nitric and hydrochloric acids to remove any traces of base metals which might be present. It was found that traces of graphite were mechanically introduced into the metal, during electrolysis, and while these were not easily removed by the washing and acid treatment described they could be almost completely eliminated, by boiling with a mixture of concentrated nitric and sulphuric acids, until fumes of sulphur trioxide were evolved.

The electroyltic process appears to be as satisfactory as the sodium reduction. The metal produced is coarser and denser. Both electrolytic and sodium reduced metals contain small quantities of impurities, chiefly oxide, which are removed during the sintering process employed for consolidation.

Recapitulation and Future Prospects

The production of tantalum as described above explains to a large extent the reason for the high cost of the final product. The ore is expensive, a high-grade tantalite is sold for about 60 shillings per pound of Ta_2O_5 contained, this is equivalent to about 75 shillings per pound of tantalum. After allowing for the losses at various stages the cost of the tantalum as ore in the final sheet is well over 100 shillings per pound. The equipment required for operations with hydrofluoric acid is expensive and requires considerable maintenance. Hydrofluoric acid, as well as being difficult and expensive to handle, is costly in itself

as is the potassium fluoride which is also used. Both of the reduction processes used in industry (i.e. the sodium reduction and the electrolysis of fused salts) are expensive. They are both operated only on a small scale, and their annual output is comparatively small. The consolidation by pressing and sintering is necessarily costly; the presses, sintering furnace, instruments, and pumps are all very expensive items of equipment and have to be amortised against the very small output. The labour charges are high because the metal is handled in small batches. The final operations of rolling, etc., are complicated by the fact that although the metal works readily it does work-harden gradually and requires to be annealed, an operation which must be performed in a furnace operating at a high vacuum at an elevated temperature—again more expensive equipment is required.

Scrap is not too bad a problem as the metal can be embrittled by the use of hydrogen and so made amenable to crushing to powder which can eventually be reprocessed. But even so, considerable costs have been incurred in re-cycling the metal.

One apparent way to reduce costs would be to arc melt and on reading the paper[9] on the reduction of tantalum chloride by magnesium the reference to arc melting makes it appear that this is a simple operation, but more careful examination shows that a typical run produced 61 grammes of metal which presumably was the order of the size of button melted. This button was melted with a tungsten tipped electrode operating in a helium-argon atmosphere. The outer metal was very hard; only the interior was soft enough to be rolled. In any case the button would have to be melted several times and maintained in a molten state, and it has already been indicated that this is quite different from the conditions applying in normal arc melting to produce ingots. Hence it will be appreciated that the arc melting of tantalum will not be a simple matter and it is very probable that it will be too difficult to operate on a commercial scale.

The high cost of tantalite is another problem that does not promise to become easier; in fact, the tendency is for the price to rise as high-grade tantalite becomes scarcer. There is, however, the possibility that new methods for the separation of tantalum and niobium will become possible. One of these methods is separation by liquid-liquid extraction which has been described recently.[10] (This work by Werning and Higbie was carried out on tin slags.) By this method it is possible to operate with low-grade ores and, in particular, those containing larger proportions of niobium and titanium, become amenable to treatment. The liquid-liquid method of separation depends on the preferential extraction of tantalum, from mixed aliphatic ketone solutions containing mixed anhydrous pentachlorides, by 12N hydrochloric acid. The system methyl isobutyl ketone —diisobutyl ketone—12N hydrochloric acid was used to produce relatively pure tantalum and niobium oxides. Starting from an original mixture of 50/50 tantalum/niobium the acid extract contained tantalum and niobium in the ratio of

$$84.4\left(\frac{Ta}{Ta+Nb}\times 100\right) \text{ and } 15.6\left(\frac{Nb}{Ta+Nb}\times 100\right)$$

and the organic phase had the ratios 2.4 × 97.6. This was in a single stage extraction and a multiple stage gave values of 98.8 and 1.2 in the acid extract and 1.0 and 99.0 in the organic phase.

Similar work is described in an earlier paper.[11] In this investigation counter-current extractions were performed in a 12-foot perforated-plate pulse column. The column was constructed from two inch bore polyethylene pipe. The system hydrofluoric acid—hydrochloric acid—methyl isobutyl ketone was employed and kilogram quantities of tantalum and niobium oxides were produced. The oxides produced were of high purity: 99.85% Ta_2O_5 and 99.7% Nb_2O_5.

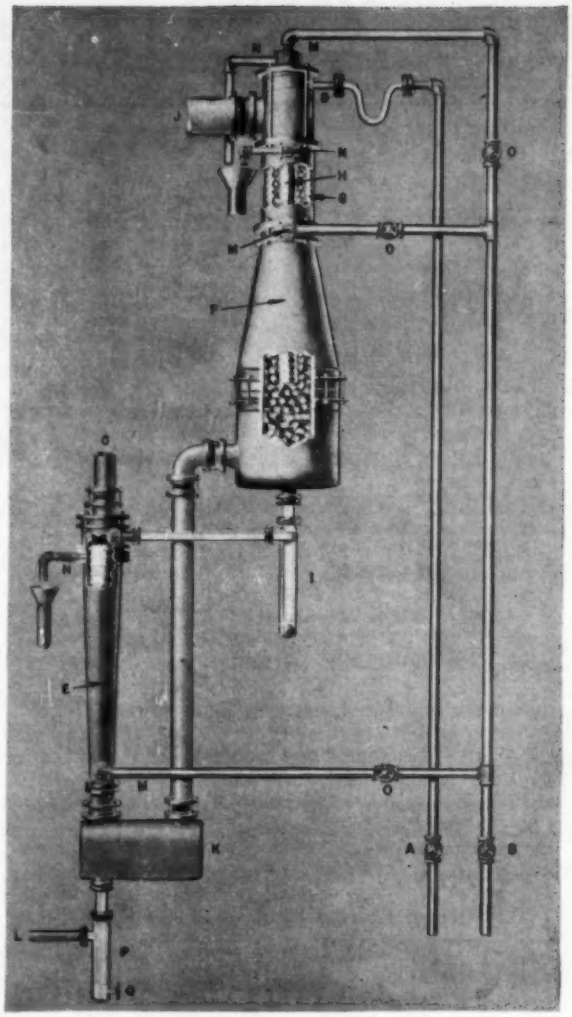


Fig. 4. This two-stage absorption unit, designed for production of strong hydrochloric acid, has all the heat-transfer surfaces of tantalum. The quantity and strength of acid are controlled by the valves A and B. Other details are: C - gas inlet; D - make-up water inlet; E - tantalum condenser-absorber; F - packed absorption tower; G - tantalum condenser; H - tantalum bayonet cooler; I - tower trap; J - exhaust gas outlet; K - surge chamber; L - acid delivery outlet; M - cooling water inlets; N - cooling water outlets; O - cooling water adjustment valves; P - acid trap; Q - acid drain. (Illustration: Fansteel Metallurgical Corporation.)

The investigators of the separation of tantalum and niobium by liquid-liquid extraction produced oxides of high purity, but information on the cost of production is not available and it has still to be shown that the results achieved can offset the use of comparatively expensive organic solvents, together with the cost of the special type of plant required.

Reduction to Tantalum

The reduction of tantalum pentachloride with magnesium to produce tantalum was described in 1947.[8] In

this work powdered tantalum pentachloride was mixed with a 10% excess of magnesium turnings together with potassium chloride which formed a liquid bath with the magnesium chloride produced by the reduction.

The mixture was heated in an iron or pyrex tube and the reaction initiated by heating at one part to over 450°C. The metal powder was recovered by washing with water and dilute hydrochloric acid. Yields of over 98% were obtained for laboratory experiments but no large-scale reductions are described. At the end of 1954 further work was described[9] by investigators at the U.S. Bureau of Mines, who applied their experiences of the Kroll zirconium process to the production of tantalum. Tantalum pentachloride was produced by the chlorination of tantalum scrap. (Alternatively tantalum carbide was prepared by the reduction of tantalum oxides by carbon.) The chloride was placed in a silica boat inserted in a horizontal two-inch borosilicate glass-tube with three zones. In the middle zone a graphite boat containing the magnesium was heated to 750°C. The chloride was sublimed and, with the aid of a flow of helium, passed over the heated magnesium. Unreacted chloride which condensed in the cooled end zone was then heated, and the helium flow reversed. This procedure was repeated until all the chloride was reduced.

After cooling, the product was heated in a vacuum furnace to 900°C to remove the magnesium chloride. The final product was a pyrophoric metallic sponge which required careful conditioning before exposure to the atmosphere. The sponge was arc-melted to produce a button of metal which was cold rolled without difficulty. A reduction efficiency of 77.5% was reported. It was thought that large-scale production was possible, but materials of construction for a larger design were considered to present a difficult problem since iron was seriously attacked by the tantalum pentachloride at the reduction temperature. (Tantalum chloride tends to decompose when heated, yielding chlorine which attacks the iron vessel.) As the product of the attack on the iron (iron chloride) was volatile, this was later reduced by the magnesium so that the final metal would be badly contaminated by iron. It appears therefore that the conversion of this process to large-scale production is not a simple matter, and so far there is no record of commercial production by this method.

Consolidation of Tantalum Powder

Tantalum powder is usually consolidated by a powder metallurgical technique. The high melting point of the metal and its reactivity towards ceramics and graphite at this temperature make it difficult to melt without contamination. The use of a very high vacuum is essential not only to avoid embrittlement by oxidation, but also to assist in the removal of gases evolved during the sintering process. Although it has been claimed[9] that the tantalum has been arc-melted successfully, the scale of operations were small and it is doubtful if large-scale production is possible with tantalum powder containing residual oxygen and carbon. These impurities are only removed by prolonged treatment at a high temperature; such conditions are obtained in the sintering process. The period during which metal is molten in the arc process is comparatively short and does not permit the completion of the reaction between the carbon and oxygen and the removal of the product of this reaction.

It is interesting to note that von Bolton of Siemens & Halske, who was the first to produce ductile tantalum, used an arc method for consolidation of his powder. Small compacts of tantalum were melted on one side with an arc and then turned over and the operation repeated on the reverse side. Arc melting in this manner, i.e. playing an arc over the surface of the metal, provides enough time for the gases to be evolved but this is quite different from the arc melting technique employed today in the titanium and zirconium industries when a consumable electrode is rapidly melted in a water-cooled crucible.

There are three distinct outgassing stages which occur during the sintering of a compact of tantalum. The rate of outgassing is controlled by the rate of heat input so that the pumps can maintain control and not allow the pressure to exceed a fixed maximum, say 50 microns. The first outgassing stage is at 400 to 600°C when adsorbed moisture and adsorbed hydrogen are evolved. This stage proceeds rapidly and the temperature can be raised without much hesitation until a temperature of 1400 to 1600°C is attained. At this point the oxygen, present as a lower oxide of tantalum, and residual carbon react and the temperature must be held until the reaction is completed and the pressure drops. The final stage, which occurs about 2000-2200°C is the evolution of residual tantalum oxide which was left after the oxide/carbon reaction. The oxide is evolved as a lower oxide, which appears to correspond to the formula Ta_2O_4.

Too rapid sintering of the bars can result in "blown" bars which are useless and are the result of sintering of the outer surface of the bar before the gases are completely removed from the middle. The bar after sintering has a density of 14.5 to 15 g/c.c., it is strong and can be rolled or worked but to ensure maximum ductility it is preferred to re-sinter after some mechanical working. In the final sintering the temperature is raised to 2400°C and held there for a period of three hours.

The method of carrying out the sintering operation varies. Siemens & Halske[1] heated the pressed bar by radiation from a cylindrical-tube-resistor composed of tungsten rods. The heating periods were rather prolonged and the resistor fragile. The more usual method is to heat the bar by direct resistance, i.e. by passing a heavy current through the bar in a method similar to that employed for tungsten and molybdenum. The operation is performed in a high vacuum which considerably complicates the design and operation of the furnace. The pressed bars are quite strong and can be clamped at both ends to water-cooled copper electrodes. The vacuum furnace shown in Fig. 1 can sinter the bars in one operation. The bars sintered in this furnace weigh about 1¼ kilos each. During sintering the bars shrink as much as 15%. The vacuum pumps used for the evacuation of the furnace are an oil diffusion pump backed by a mechanical pump.

The sintered bar can be worked readily as the fully sintered metal is as malleable and ductile as mild steel. All fabrication is performed cold because of the activity of the metal towards the atmospheric gases at elevated temperatures.

REFERENCES

[1] Berry, B. E., Miller, G. L. and Williams, S. V. "Production of Tantalum in Germany." B.I.O.S. Final Report No. 803, Item Nos. 21, 22. H.M.S.O., London, 1947.

[2] "Acid Handling." Imperial Smelting Corporation Ltd., Avonmouth, Bristol.

[3] Zeppelin, H. von. "Darstellung von Zirkonium Durch Reduktion von Zirkonchlorid mit Magnesium." *Metall u. Erz*, 1943, **40**, 252.

[4] Sittig, M., "Handling Sodium," *National Safety News*, July 68(1), 26, 1953.

[5] Thorpe's Dictionary of Applied Chemistry. "Sodium," Vol. X, 4th edition, p. 804, Longmans, Green & Co. Ltd., London, 1950, **27**, 1166.

[6] Balke, C. W., "Columbium & Tantalum." *Ind. & Eng. Chem.* 1935.

[7] Driggs, F. H. and Lilliendahl, W. G., "Preparation of Metal Powders by Electrolysis of Fused Salts." *Ind & Eng. Chem.* 1931, **23**, 634.

[8] Isaza, J. P., Shaler, A. J. and Wulff, J. "Tantalum Powder by Magnesium Reduction." Metals Technology, **14**, Tech. Pubcn. 2277, 1947.

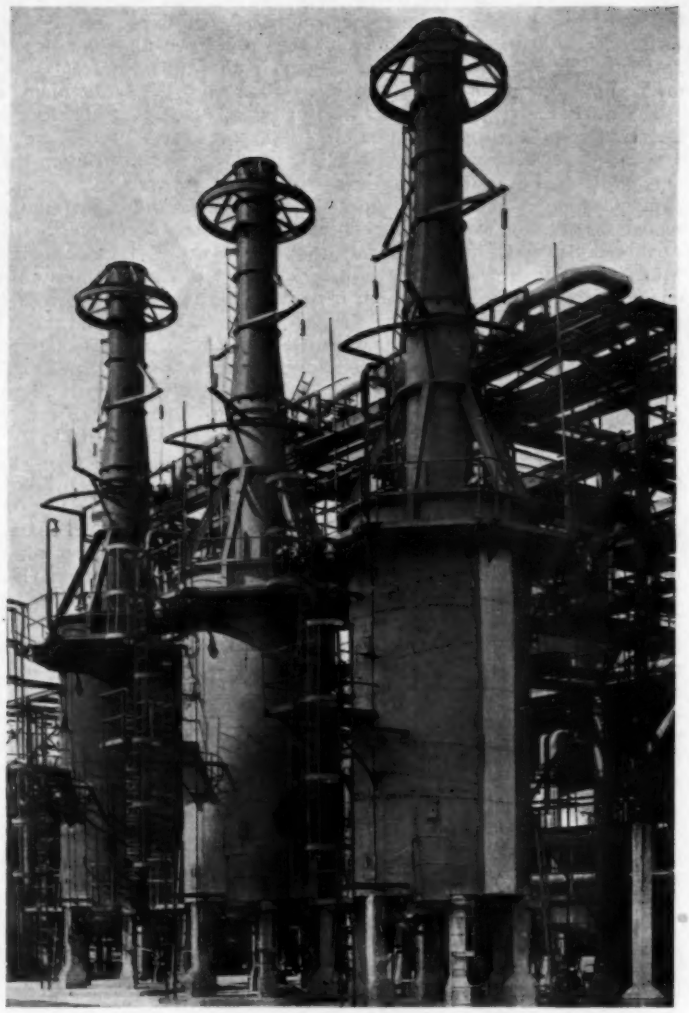
[9] Johansen, H. A. and May, S. L., "Ductile Tantalum by Kroll Process." *Ind. & Eng. Chem.* 1954, **46**, 2499.

[10] Werning, J. R. and Higbie, K. B., "Tantalum and Niobium—Separation by Liquid-Liquid Extraction." *Ind. & Eng. Chem.*, 1954, **46**, 2491.

[11] Werning, J. R., Higbie, K. B., Grace, J. T., Speece, B. F. and Gilbert, H. L. "Separation of Tantalum and Niobium by Liquid-Liquid Extraction." *Ind. & Eng. Chem.* 1954, **46**, 644.

[12] Schwarzkopf, P. "Engineering Properties of Sintered Metals," *Product Engineering*, April, 1946.

[13] "Acid-proof Tantalum Equipment for Chemical Operations." Fansteel Metallurgical Corporation, North Chicago, Illinois, U.S.A., 1951.



Three typical Petro-Chem Iso-Flow furnaces made by Birwelco Ltd. These furnaces are employed as steam superheaters, and each has a heat absorption capacity of over 5,000,000 Btu per hour.

Radiant-type upshot furnaces are finding wide use in oil refineries and chemical factories. These furnaces are now being manufactured to Iso-flow designs in Britain.

THE UPSHOT FLUID HEATING

THE vertical cylindrical furnace has been used for practically all duties in oil and chemical plants where fluid heating is required, since the original cylindrical furnace invented by Louis de Florez was employed for refinery use some 25 years ago. These include crude topping, heating reduced crude for vacuum distillation, light and heavy gas oil cracking, evaporating and superheating oil vapours for catalytic cracking processes, heating up lubricating oils and solvents, heating fat absorption oil for casing head production, high and low temperature steam superheating, heating bitumen products for loading purposes, domestic heating, steam generation, heating heat-transfer mediums, air heating for use in jet engine testing, and air heating for use in wind tunnels.

The cylindrical furnace, because of its greater efficiency, is gradually replacing the old type of horizontal rectangular heater known by various names such as box-type heater or horizontal heater. The box-type heater has developed from an elementary form of tube coil placed in a muffle and its development has been haphazard.

de Florez's basic principle was that the most efficient form of heater would have uniform heat absorption throughout the length of its tube coil. In consequence, the maximum heat absorption rate would be low, and close to the average rate. In this way the heat absorption rate throughout the furnace could be raised, reducing the size of the furnace and increasing its adaptability and efficiency. The ideal form of furnace would be a sphere around which the tube coil would be wound with a point source of heat in the centre, the whole enclosed in a refractory sphere so that the heat would be uniformly reflected on to all parts of the tube surface. Such an arrangement is not, as yet, a practical engineering proposition, although the use of atomic fuels may point the way in this direction.

Practical Realisation

de Florez decided that the nearest practical form was a cylinder, and by suitable adaptation he constructed the first cylindrical vertical heaters for the Sinclair Refining Company of East Chicago. These had the burners in the top and a refractory cone in the base. As will be described later, he managed to obtain a reasonably uniform heat absorption rate throughout the coils which were arranged vertically round the periphery of the cylinder. He achieved high efficiency by the use of Lüngstrom-type air heaters to raise the temperature of the forced draught. The Petro-Chem Development Company of New York have recently developed a similar type of heater, but with the burners at the bottom, and a heat resisting alloy steel cone at the top. The natural draught generated by this arrangement is sufficient to produce the necessary combustion and heat distribution within the heater for all normal duties. It is only where special considerations call for high efficiency that air heaters are used in conjunction with this furnace.

Both types of heater are very adaptable and can be arranged to suit substantially any required oil heating curve. In thermal cracking, it is required to heat the oil to be cracked to a predetermined temperature as rapidly as possible and then to maintain it at a certain temperature for some time. In crude topping and for heating gas oils for catalytic cracking it is advantageous to have little or no thermal cracking and consequently no soaking time.

In practically all applications of oil heating by direct firing the oil is forced through the tubes in series flow, although there may be several heating flows in the same furnace. To reduce pressure drops through the oil-heating coils, it is often desirable to parallel the tubes at the point of vaporisation. This is usually done on vacuum distillation units or where it is necessary to vaporise the oil and superheat the vapours. Where any superheating of vapours is required there may be several parallel flows. Where it is necessary to handle large volumes at extremely low pressure drops, it has been found quite satisfactory to have a large number of parallel flows.

The design of furnace must be chosen to provide the type of heating curve required for the duties it is to perform. As was mentioned earlier, some processes may require soaking time at a fixed temperature, while for

FURNACE

others it is advantageous to have little or no soaking time. In selecting the size and type of coils required, mass velocity, pressure drop, the chemical composition of the charge and the thermal efficiency desired must be considered. The most desirable selection will be reached as a result of trial and error calculations, guided by experience and capital cost requirements. A detailed explanation of the method by which basic design data are obtained has been given by L. A. Mekler[1] and other workers.

After the basic requirements have been calculated, it is usual to base the design on that of a successful furnace already in operation; there is considerable experience on which to draw for approximately thirteen hundred of these furnaces have been built. The factors affecting the individual designs of the heater, in addition to coil dimensions, are the length/diameter ratio of the furnace, the angle and size of the cone, and the dimensions of the

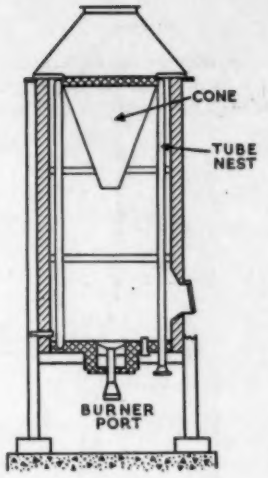


Fig. 1. The simple type of radiant upshot furnace, showing refractory cone.

annular space. It has been found that the larger heaters present simpler design problems than smaller ones, as the conditions created by a large combustion chamber give more stability and control over the flame pattern. Further, the length/diameter ratio will vary, not only with the size of the heater, but also with the heat release.

Cylindrical furnaces of these types have been successfully used for many different duties in oil refineries and chemical works. They range from examples calling for a 180,000,000 Btu/hr absorption (Fig. 2) down to the very smallest units (Fig. 1), which are designed more for economy of construction than for efficiency, and where only a few hundred thousand Btu/hr are absorbed in the tube coil.

Comparing a Vertical Cylindrical Furnace with Box-Type Heater

It is well to give some consideration to a comparison between the heat absorption rate in the tubes of a vertical cylindrical furnace and the box-type heater. Numerous experiments have now been conducted by research engineers, and the following facts have been obtained. In the box-type heater there are a number of tubes throughout the heater where the heat absorption rate is relatively high, say up to 27-28,000 Btu per hour per sq. ft. In other parts of the heater, such as in the corners of the box formation, and at the base near the burners, the heat absorption rate is of the order of 3,000 Btu per hour per sq. ft., or less. In order to limit the hot spots which might develop and cause choking, it is necessary to design a box-type heater with a comparatively low average specific heat absorption rate, say 7-8,000 Btu per hour per sq. ft.

On the other hand the vertical cylindrical heater can be designed so that there is no greater variation than 10% in the heat absorption rate throughout the length of each tube. For example, if the heater is designed for an average heat absorption rate of 10,000 Btu per hour per sq. ft., then at the centre of the tube, half-way between the top headers and the bottom headers, the heat absorption rate will be of the order of 11,000. At the bottom of the tubes the heat absorption rate will be about 9000. At the arch, that is where the annular space is reduced by the cone so that the gases are pressed against the tubes with increasing velocity, compensating for the loss of radiant heat, the rate will be 9000 Btu per hour per sq. ft.

Other advantages of the cylindrical heater are that being of cylindrical form and standing vertically, no special arrangements are necessary to allow for expansion of the heater shell, and the tubes, standing as columns, are little susceptible to distortion compared with those lying hori-

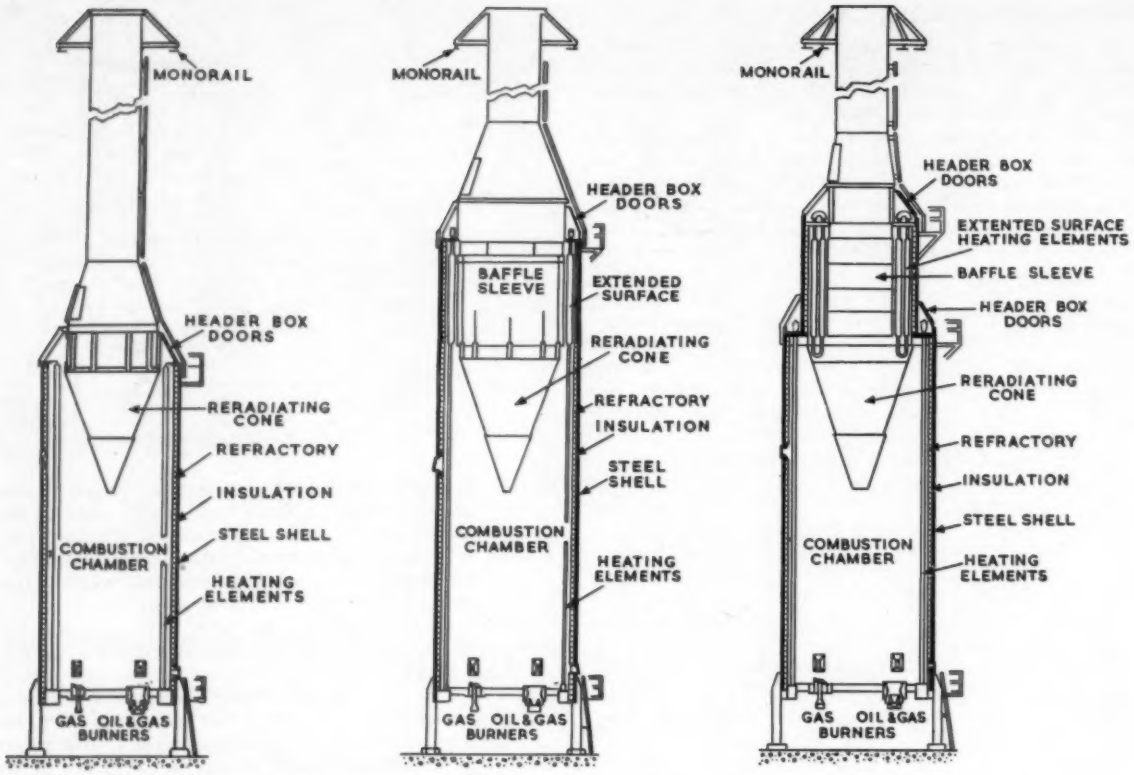


Fig. 2 (*left*). *Typical large radiant-type upshot furnace with re-radiating cone. Fig.* 3 (*centre*). *Large upshot furnace with convection zone above re-radiating cone. Note that the tubes become finned in the annular convection zone. Fig.* 4 (*right*). *Upshot furnace with separate finned tube convection section.*

zontally on hanger brackets. Several further advantages accrue from having the tubes in a vertical position. Tube cleaning becomes a simple matter since the cleaning apparatus will travel down the length of the tube under the force of gravity and can then be hauled back by pulley blocks suspended on the monorail which runs round the top of the stack.

Further, tube withdrawal is simple, facilitated by the pulley blocks on the monorail. Vertical withdrawal of the tubes gives economies in the use of ground space in the plant, which is becoming increasingly important to the design engineer. In the case of a horizontal heater where the tubes have to be withdrawn horizontally, an area, at least as large as the heater itself, must be left free in order to allow the tubes to be withdrawn. With the vertical heater it is only necessary to allow a small clear space round the periphery of the heater to provide facilities for tube removal and replacement.

More Complex Cylindrical Furnaces

Where greater efficiency than that obtainable in the simple radiant-type furnace is required, various forms of convection sections can be added. The most useful method is shown in Fig. 3, where the convection surface consists in an extension of the radiant tubes in an annular space formed by a cylinder of refractory material placed above the heat resisting cone at the top of the furnace. By the use of extended surfaces, such as Brown Fintube longitudinal fin channels, on the tubes in the annular space, the heat absorption rate in the convection section can be arranged to be the same as that in the radiant section. There are, however, many applications where it is desired either to pass a different fluid from that in the radiant section through the convection section coils, or where higher efficiency is required than can be provided by this form of radiant-convection design.

In such cases a separate convection section is desirable, and this may be provided above the radiant section but below the stack as shown in Fig. 4. Different types of header or welded return bends may be chosen according to the application, to ensure that there is no possibility of plugging or coking. Where further improvement in efficiency is required it is possible to insert yet another coil above the convection coil illustrated in Fig. 4. For the highest efficiency further heat can be removed from the combustion gases in a Lüngstrom air-heater used in conjunction with forced draught to raise the temperature of the intake air.

Applications

Within recent months, a licence has been issued by Petro-Chem Development Company for the manufacture of their cylindrical furnaces in the United Kingdom. Already furnaces have been manufactured in Britain for use in such widespread applications as catalytic cracking, vacuum distillation and crude topping. Furnaces have been provided as very high temperature steam superheaters, alkylate heaters, tetramer heaters, D.M.K. converters, Dowtherm heaters, air heaters and for many other uses in the chemical industry. Other variations of the same basic design such as steam generating units and helical coil units have been made where cheapness rather than ease of maintenance is desired. In fact, it may well be said that the cylindrical furnace has earned its place in the forefront

of the oil refining and chemical industries, and that it can be designed for any type of duty and any required efficiency that are normally encountered.

The main advantages claimed for this furnace may be summarised as follows:

1. Attractive first cost for equal thermal efficiencies.
2. Higher average rates of heat absorption possible.
3. Less floor space required.
4. Maintenance of refractories practically nil. Other maintenance operations more easily carried out.
5. Greater flexibility in the mechanical design, and no special arrangements required for expansion.

REFERENCES

[1] Mekler, L. A., *Oil and Gas J.*, 1955, **54**, 108.

Pilot Plants are *not* Obsolescent

by S. A. GREGORY, B.Sc., M.I.Chem.E

AT the present time of the year one of the most convincing and irrepressible sounds of optimism in nature is the dawn chorus of the birds. Whilst I was listening to these sweet singers in the twilight which separates night from day I recalled the recent American Letter* entitled "Twilight of the Pilot Plant?" My first question in the light of the newly breaking day was to find which twilight it was to which the American Correspondent, Lincoln T. Work, referred. Was it the twilight which comes between day and night, or was it the twilight which comes between night and day?

My own reading of the general situation in chemical engineering is that we have to look forward to a period of improvement in pilot plants. The function of pilot plants and pilot plant work is to provide guidance in the transition from the process as seen in the laboratory to the creation of the design and the commissioning and operation of the full-scale plant. The early navigators at sea preferred to keep the coast in sight. Later, under a clear sky it became possible to use the stars as a guide to position and movement. Then came the compass, the sextant and the chronometer. Today, radar enables navigation in fog and darkness, permitting ships to travel at full speed under conditions which previously would have stopped all safe progress.

There are very few processes in which it is possible to to go from the laboratory scale directly to the industrial level on a genuine economic basis without pilot work. The purpose of pilot investigation is to provide the cheapest total investment to produce a given rate of production. The cost of the investigation forms part of the total investment; therefore, it is extremely important to obtain our information from the pilot investigation with a minimum of expenditure and a maximum of certainty. Moreover, it is usually necessary under conditions of competition to obtain the required answers with as little delay as possible.

Those of us whose business is the development of new processes to the industrial scale are frequently obliged to work with a depleted team and insufficient time. We look forward to the days when we shall be able to use more positive and accurate pointers to aid us in achieving the final plant specification, enabling us to obtain good results with less men and less time. At present, unless the process is only a slight variation on one which already exists, it is necessary to test each step. The steps need not be co-ordinated nor of comparable throughputs. In the case of some unit operations it is possible to work such steps as are relevant on a comparatively small scale with reasonable assurance that it will be possible to magnify the scale of operation without undue risk. For example, it is possible to predict the performance of a large rotary vacuum filter from tests with a small filter leaf, which will give capacity data, and then check the likelihood of blockage on a small rotary unit. Practical filtration for the purpose of getting pilot plant process material may be done with a simple Nutsch type filter. The situation with regard to rotary vacuum filters is by no means perfect, since it would be good to have statements from the filter manufacturers regarding the reliability of capacity prediction, and, further, a cheap and really small test rotary vacuum filter would be warmly welcomed.

In the case of the vertical tube evaporator it is believed that tests on a single tube enable adequate prediction of performance on a large bundle of tubes, but little published evidence is available to support this belief. Such a kind of information is necessary to enable fair specification of the duty of a large plant. For evaporation of process liquors sufficient to feed other units of the pilot plant it is permissible to use any kind of evaporator which is available and suitably constructed, e.g. a jacketed pan.

In short it may be said that even the well-known unit operations are not yet plain sailing when it comes to the crucial question as to whether it is possible to put a new process on the industrial scale without any work on experimental plant in between.

A sign of the times is that the Institution of Chemical Engineers is planning to hold a conference in 1957 on the subject of increasing the scale of operation of chemical plant. An important aim of such a conference should be to establish better information regarding the reliability of proposals for the design of large and new plants. At present the undertaking of design experiments on nearly every step on a new process resembles the navigation of the ancients who liked to keep the shore in view.

The accumulation and analysis of the sort of data which the 1957 conference promises may be a move towards the establishment of charts to help our navigation, even if the charts be of the type which mark some regions as "Here be great pitfalls!" Such an advance would help us toward greater awareness of the directions in which it is possible to go boldly as well as those where we need to use caution.

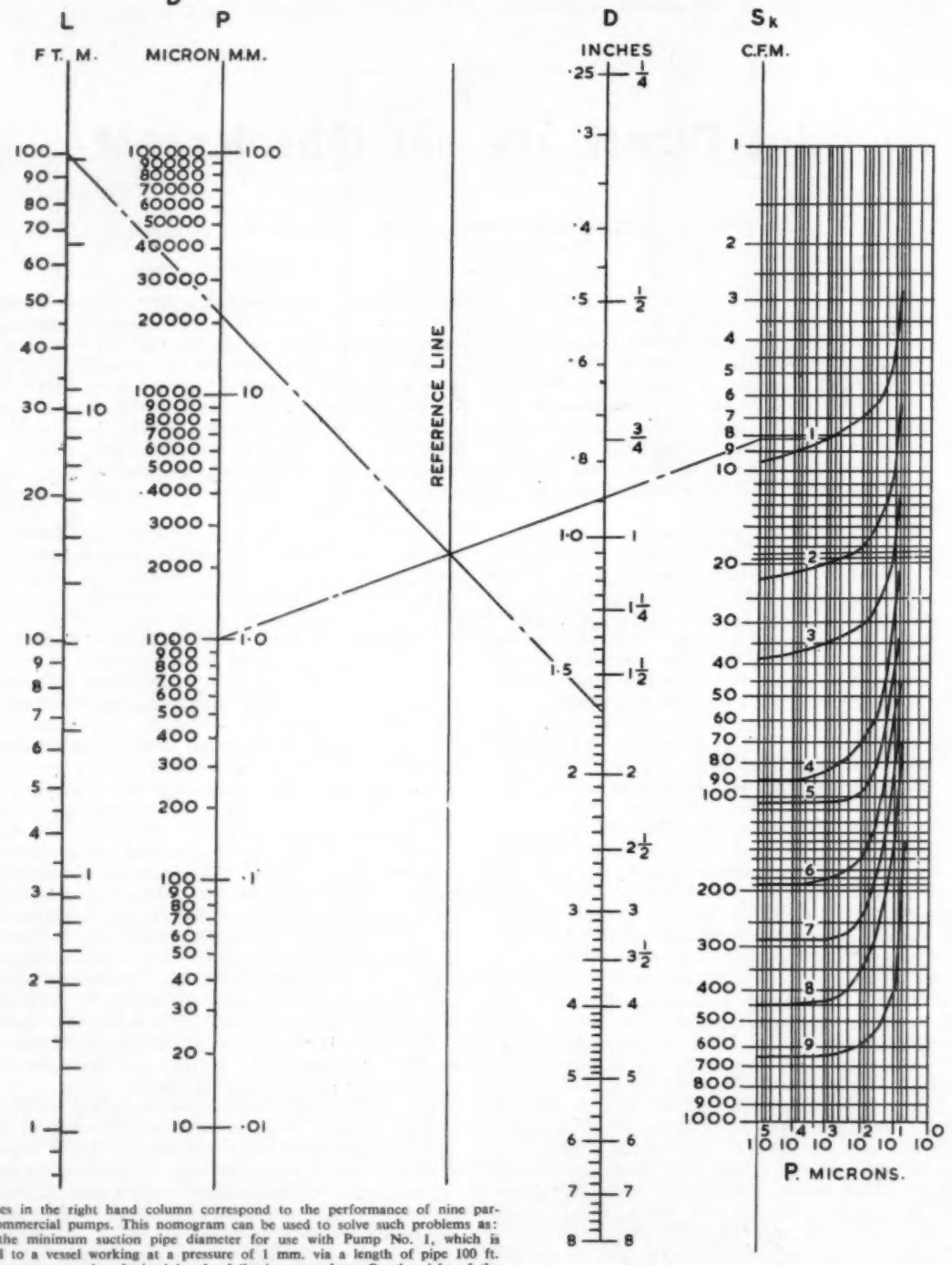
Therefore I feel that perhaps we are passing through a period of twilight before the early day. The birds are singing loudly and it is to be hoped that they will not be disappointed. They have to pass through the heat of the day before they can return to settle down in their nests. Similarly, chemical engineers may be talking hopefully about the departure of the pilot plant, but the day is only just beginning. Before the day of the pilot plant ends there is a tremendous amount of work to do.

*British Chemical Engineering, 1956, **1**, 44.

NOMOGRAM No. 2 BRITISH CHEMICAL ENGINEERING

$$P = 9{\cdot}75\,\frac{S_k L}{D^4}$$

P = PRESSURE IN SYSTEM MICRONS. D = MINIMUM PIPE DIAM. INS
L = LENGTH OF PIPE FT. S_k = PUMPING SPEED OF PUMP CFM



The curves in the right hand column correspond to the performance of nine particular commercial pumps. This nomogram can be used to solve such problems as: what is the minimum suction pipe diameter for use with Pump No. 1, which is connected to a vessel working at a pressure of 1 mm. via a length of pipe 100 ft. long. The answer can be obtained by the following procedure: On the right of the nomogram there is a chart connecting vessel pressure P with pumping speed S_k hence draw a horizontal line from the point of intersection of the curve for pump No. 1 and the 1 mm. pressure line to meet the S_k line at 8.2 c.f.m. Join the point 8.2 c.f.m. on the S_k line to the 1 mm. point on the P line. Join the 100 ft. point on the L line to the intersection of he previous line with the Reference Line and extend to meet the D line at 1.7 inches. Hence the correct size of suction pipe diameter is the next standard size larger, i.e. 2 inches.

AMERICAN LETTER

Bridging the Gap

by Dr. Lincoln T. Work

THROUGH the ages, the process of grinding cereal grains, minerals, and other materials has served man well. Today it can be said that much has been achieved and much is understood about this operation. The old forms of grinders, little changed over the years, are being supplemented by new devices which grind material all finer than about a tenth the size of the 200 mesh sieve, i.e. to a maximum size of .005-.010 millimetres (5-10 microns). On the other hand, there are much finer materials which might be advantageously produced by grinding, if it were possible. Reinforcing materials for rubber serve best at hundredths and tenths of microns, while pigments give optimum hiding qualities around a half micron. To make these, other processes are employed. Some are formed from the vapour phase, and others are precipitated from liquids. Often the precipitates are too fine and need to be calcined to cause the desired grain growth. That has left a gap which grinding does not fill, and it is the unusual occurrence to find ground products comparable in size to pigments. The newest developments tend to close that gap whereby finely pulverised products approach the size of more costly pigments prepared by precipitation and calcination or by vapour condensation.

The classical grinding machines—jaw and gyratory crushers, rolls, ring-rolls, ball-rolls, hammer, disc, ball and tube mills, etc.—are well known to engineers. Each has a place in the reduction of large feed down to fine mesh and to sub-sieve sizes. Hard materials are generally ground fine with slow speed mills which have relatively inexpensive wearing parts, while the high speed mills give rapid reduction of softer material. Grinding in liquid media is generally associated with other wet operations or where the dispersion in liquids tends to prevent caking or serves its own useful purpose. Costs of drying usually prevent wet grinding for its own sake.

In the normal course of grinding, the large pieces fracture into a few of the next smaller size and an additional group of sizes down to impalpable powder. Then, with further action, the largest of these are progressively fractured with an increasing accumulation of fines. Thus there are many particles formed of fractional to a few microns size as grinding progresses; but there is also some size, often many-fold larger, where the mill action functions so slowly as to be ineffective. As a result, the total product fails to develop low micron fineness and the extension of surface is limited. There is a partial remedy through classification. Those devices of this class which effect separation in air or other gases are generally large and operate at relatively low velocity. Even though they effect separation with centrifugal action, the cut is often poor, i.e. the fines in the oversize and the oversize in the fines become too great. Better results are usually obtained with classification in liquid particularly when centrifugal action is employed. It is difficult to become specific about these devices as so many factors affect them; but some broad generalisations will be risked to illustrate roughly where these machines make their cuts. In dry classification, top sizes of product around 200-325 mesh (14-44 microns) are not too difficult to obtain, and separations may be carried down to 10-20 microns, with only a few cases much below that. Wet classification is fairly simple at 20 to 40 microns and with care may go to around 10 microns. Centrifugal devices, either using rotating parts or directing the stream into rotation, effect separation down to about 5 microns with a few cases running down to 2-3 microns. Liquid separation goes with wet grinding and suffers from the costs of drying and possible further milling to disperse the cake.

Jet Grinding Mills

Jet grinding combined with high energy classification has produced materials having low micron size. The Microniser* and the Reductioniser are examples of this type of mill. These devices function by action of fine jets of air or steam which are injected at an angle into a chamber approximately circular in peripheral form. Within this periphery is a restricted chamber to which material is fed from the inner portion and this material is activated by the forward drive imparted by the jets. Naturally, it tends to swing outward under centrifugal action and the particles ride around the periphery in a suspension layer which, as it passes a jet, is suddenly disrupted under the high degree of turbulence.

The particles strike upon each other in space and become fractured and the coarser particles again resume their peripheral flow until, after several jet actions, they are fully disrupted. The jet fluid after expansion also acts as a conveying fluid for the fine particles and they move inward in the device in a spiral path with the fluid until those which are fine enough to be displaced inward pass to the outlet and the collector. This same principle, a variant of the Reductioniser, is being employed for sharp cuts in low micron sizes.

The process of fine grinding, even with classification, tends to be relatively costly. However, if it is viewed in the light of the tremendous amount of new surface developed, the cost is not disproportionate. Where sieve mesh grinds in quanity may be a few tenths of a cent a pound, micron size grinds which result in five to twenty-fold increase in surface run to cents per pound. There will be cases where the cost of calcined precipitates will be less than the present cost of a grind to the same size—if it can be done; but there may well be other cases where the chemical costs are high and where the grind may meet all of the requirements. One aspect of the chemical treatment, namely purification, is likely to stand in its favour in almost every instance. The closure of the size gap around one to three microns appears feasible; but competition of grinding with the fine fumed materials is as yet out of reach. It is an interesting thought to wonder if grinding and classification to micron sizes and finer is attainable; and, if it is, how costs can be kept low enough to consider it. Some developments now in progress may bring the cost of fluid energy grinding down substantially. Allowing for the present rate of technological progress, it would be unsafe to conclude that the gap between grinding and precipitation will not be more completely closed than it is at present.

*This pulveriser and its applications was described in the article "The Fluid Energy Mill for grinding solids to sub-sieve ranges" by H. E. Kingston, *British Chemical Engineering*, 1956, 1, 30.

PROCESS ENGINEER'S NOTEBOOK

Remote Maintenance Work on a Nuclear Reactor

WHEN the nuclear reactors at the U.K. Atomic Energy Authority's Windscale Works were being designed it was thought that equipment subjected to radiation could not be maintained and as far as possible all moving parts were situated outside the "biological shield." An exception to this principle was the gear for inspecting the cartridge charge in the reactor. It should be mentioned that the Windscale Reactors are graphite moderated and cooled by air which is "pushed" through the reactor space.

In time, however, a number of parts inside the biological shield developed faults and as a result the problem of carrying out maintenance work upon these parts arose. Such problems had not been allowed for in the original design of the reactor. Special tools and procedures had to be developed to cope with the situation.

The notebook of this issue devotes its space to a description of some of the devices and procedures which were used in this work, as outlined recently in a paper read to the Institution of Chemical Engineers by the Works General Manager at Windscale, Mr. H. G. Davey, O.B.E.

Retention of Reactor Charge

An outline of a reactor is shown in Fig. 1. One of the problems which was successfully overcome was the uncontrolled ejection of the charge from the graphite channels. The charge is introduced in the form of cartridges which are placed on boats which are linked together and secured to the lattice. This unwanted discharge of cartridges was believed to be caused by failures of the boat linkages and the solution was clearly that of providing more durable linkages in the future. There was however the immediate problem of not interrupting the operation of the reactor for any substantial period, which meant making some device for retaining the reactor charge.

The method finally chosen consisted in fixing vertical rods across the openings of the channels in order to keep the boats containing the cartridges in place. The back face of the graphite lattice carries a number of longitudinal clips (curtain rails) which serve as supports for the rods and which impart the necessary rigidity to the restraining structure. Accordingly the rods were threaded through these clips which had previously been opened to allow them to pass through (see Fig. 2).

To put the scheme into effect required a suitable design of flexible rod as well as some means of getting the rods into position. The type of rod finally adopted was an articulated one made from $\frac{1}{4}$ in. steel wire-rope over which was threaded a number of 5 ft. lengths of aluminium alloy tube. One end carried a spike and the brazed joint at the other end between wire

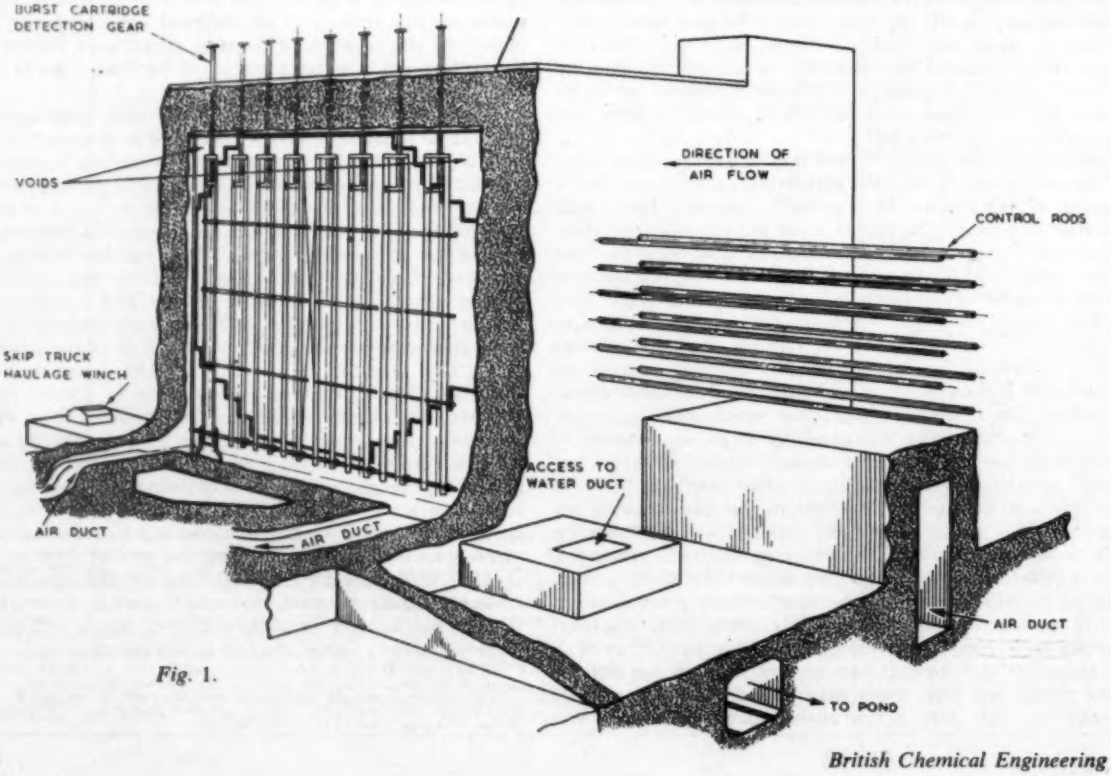


Fig. 1.

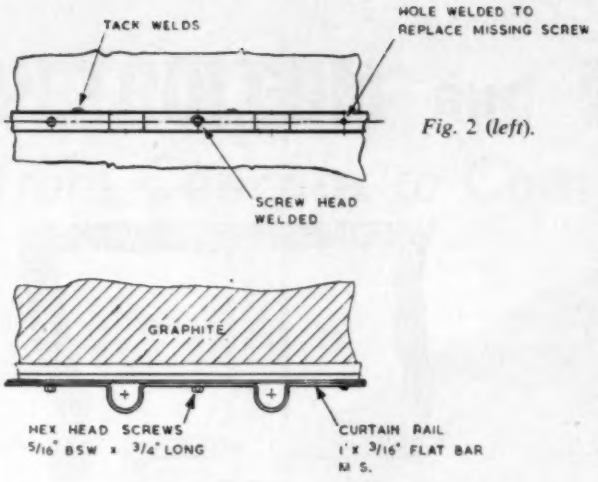

TACK WELDS
HOLE WELDED TO REPLACE MISSING SCREW
SCREW HEAD WELDED
GRAPHITE
HEX HEAD SCREWS 5/16" BSW x 3/4" LONG
CURTAIN RAIL 1" x 3/16" FLAT BAR M.S.

Fig. 2 (left).

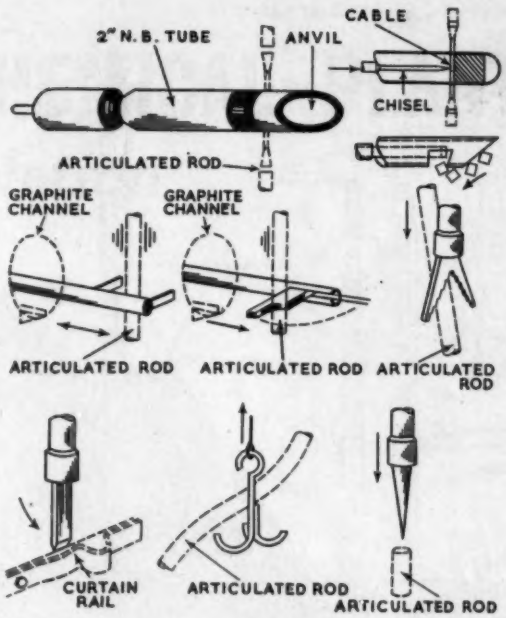


Fig. 3 (right).

and tube was faired. The total length was about 60 ft.

The roof above the lattice was provided with 4 in. holes, fitted with hollow plugs through which rods could be lowered. A means of visual inspection of the face of the graphite lattice and the attached clips was essential since the location of the rods into their proper positions across the channel openings was quite a tricky matter and had to be carried out remotely. It so happens that the reactor roof is provided with 10 in. inspection holes through which it was found possible to insert both a periscope and an introscope to give the necessary view of the reactor face. This did give a fairly good view despite some obscuration caused by the presence of the burst cartridge detection apparatus. The tools used for opening the clips to take the rods and to manipulate them into position are shown in Fig. 3.

The fitting of the articulated rods presented further problems, for when a fresh charge had to be fed to the reactor the old charge had to be removed and this meant withdrawing the rods. Consequently a further set of tools were needed to make possible the combined pulling, pushing and twisting movement necessary for removal of the rods. Fig. 3, also shows a number of tools used for this purpose.

Sometimes during these operations, when the various movements were sufficient to expose the wire rope, it

Fig. 4.

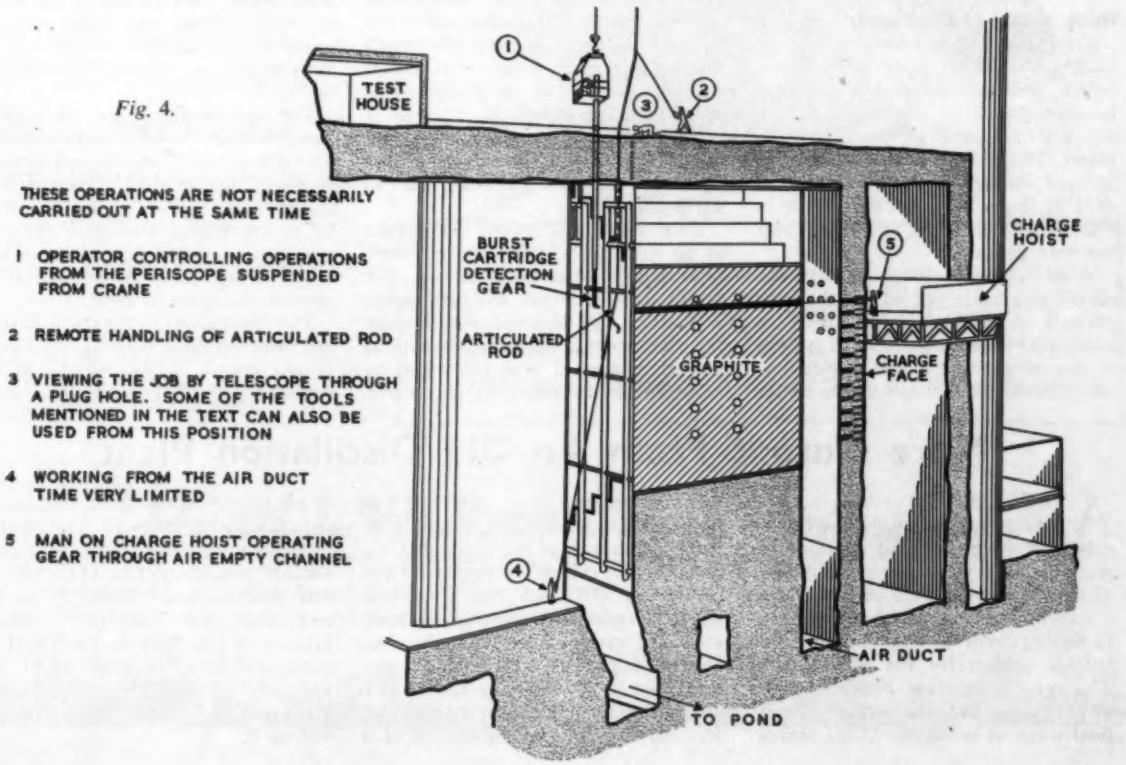
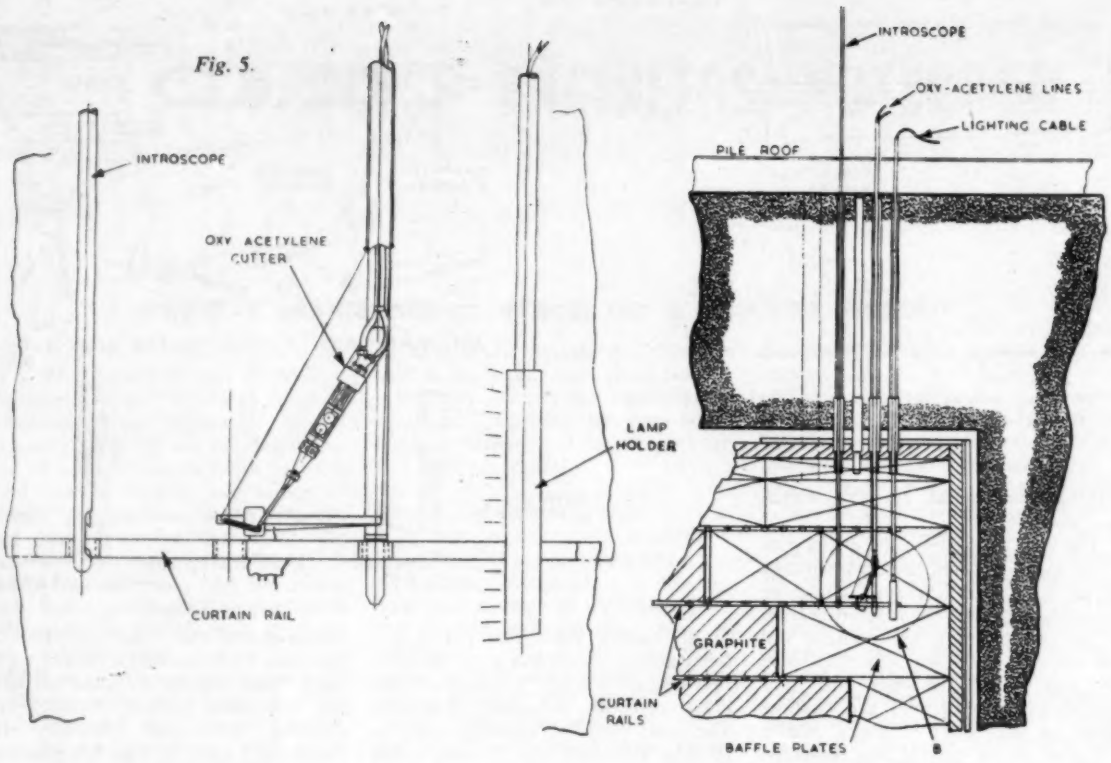

THESE OPERATIONS ARE NOT NECESSARILY CARRIED OUT AT THE SAME TIME
1 OPERATOR CONTROLLING OPERATIONS FROM THE PERISCOPE SUSPENDED FROM CRANE
2 REMOTE HANDLING OF ARTICULATED ROD
3 VIEWING THE JOB BY TELESCOPE THROUGH A PLUG HOLE. SOME OF THE TOOLS MENTIONED IN THE TEXT CAN ALSO BE USED FROM THIS POSITION
4 WORKING FROM THE AIR DUCT TIME VERY LIMITED
5 MAN ON CHARGE HOIST OPERATING GEAR THROUGH AIR EMPTY CHANNEL
TEST HOUSE
BURST CARTRIDGE DETECTION GEAR
ARTICULATED ROD
GRAPHITE
CHARGE HOIST
CHARGE FACE
AIR DUCT
TO POND

Fig. 5.



became necessary to cut the rope. A special chisel and anvil, remotely operated from the reactor face, were used for this purpose.

Fixing of Loose Baffle Plates

From Fig. 4 it will be seen that the back and front faces of the graphite lattice are stepped and the spaces between the lattice and the biological shield are sealed off by means of baffle plates. The plates are m.s. aluminium sprayed and held in position by means of ¼ in. bolts. The air flow tends to retain the front plates and to dislodge the rear plates.

After a while, following the discovery of a badly twisted and distorted plate, it was decided to investigate the condition of the baffles. For this purpose a television camera and introscopes were introduced through the inspection holes in the reactor roof and the charging holes in the charge face. Examination of the baffles showed that on the back face of the reactor some bolts were found to be missing and others loose. This situation called for remedial action, the need for which was emphasised when the motor driving the burst cartridge gear tripped-out on overload through a plate becoming loose enough to foul the gear, thereby preventing its proper operation and becoming badly bent in the process.

This recurrence caused the reactor to be shut down, and attempts were then made to force the plate back into position. The initial attempts made with articulated rods operated through the 4 in. opening were unsuccessful as the force applied was too small to make much difference to the plates.

Thereupon it was decided to weaken the plates by flame cutting at suitable points and to restore them to their proper positions by means of rods. This meant developing a remotely operated cutting technique with an oxy-acetylene torch. The manner of carrying out the flame cutting is shown in Fig. 5.

The first attempt to get the buckled plate back into position was successful, the cutting, which was viewed through an introscope, proving adequate. Subsequently the success of this operation led to the remote welding of plates to one another and to the tacking of bolt heads to the plates as a measure to prevent loosening of bolts.

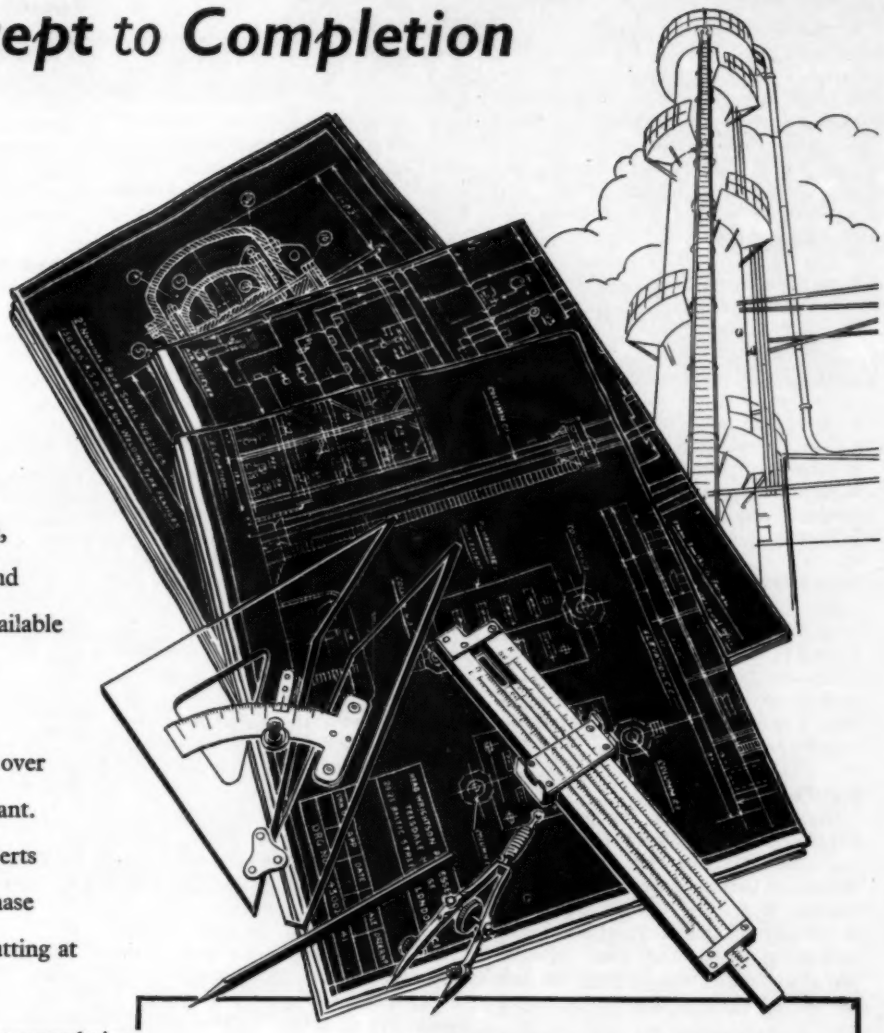
The illustrations in the above feature are based on those used by Mr. Davey in the course of his lecture to the Institution of Chemical Engineers.

More Output From An Old Distillation Plant

A PROCESS alteration confronted a manufacturer of organic chemicals with the problem of adapting his plant. In his original process a number of reaction stages were carried out in a solvent medium. Yields were found to be improved by substituting a less volatile solvent for the original one. The existing reaction equipment was able to meet the change in process; final stage of purification and separation of solvent from product was carried out by distillation, with product being withdrawn at the bottom of the column. The use of a different solvent meant that the distillation conditions were changed and a series of quick estimates revealed the fact that the desired degree of purity and output could not be obtained together. Twice as much heating surface at the re-boiler was required but the installation of a larger re-boiler was ruled out on the grounds of long delivery. The original tube-plate contained the maximum number possible of ¾ in. O.D. tubes to give total surface of 150 sq. ft. The new tube plate carried a smaller number of ¾ in. bore fin tubes with an outer to inner surface ratio of 11. The area of the new tube-plate obtained by using the bore fin tubes was 450 sq. ft.

PETROLEUM and CHEMICAL PLANT

from Concept to Completion



The complete range of our activities covers all aspects of the building of petroleum, chemical and allied plants and equipment. The services available operate from the inception of the project to the commissioning and handing over of the complete operating plant. Within the company are experts capable of handling every phase of such a programme and putting at your disposal any or all of these ten vital steps to project completion.

- PLANNING
- DESIGN
- ENGINEERING
- PURCHASING
- INSPECTION
- PROGRESSING
- SHIPPING
- SUPERVISION
- ERECTION
- COMMISSIONING

Write also for brochure H.W.P. 5301— Plant Construction Services.

Head Wrightson Processes Ltd.

TEESDALE HOUSE, 24-26 BALTIC STREET, LONDON, E.C.1

Offices at: P.O. Box 1595 **Sydney**, P.O. Box 1034 **Johannesburg**, P.O. Box 4 **Calcutta**, and 185 Bay Street, **Toronto**.

Associates in the U.S.A.: The Fluor Corporation Ltd., Los Angeles 22, New York, Chicago, Boston, etc.

376 H-A

World of Chemicals

German Platinum Catalysts

Kali-Chemie A.G. of Hanover has concluded an agreement with the Atlantic Refining Co. of Philadelphia to produce reforming or platinum catalysts under licence. It is reported that the German firm has been given sole selling rights for both these types of catalysts in most foreign countries, excluding the U.S.A.

Danish Medicinal Goods

The chairman of the Association of Danish Manufacturers of Medicinal Goods stated at the Association's recent annual meeting that the export value of Danish medicinal goods during 1955 amounted to Kr. 65.5 million of which Kr. 25 million was in respect of penicillin and other antibiotics, and Kr. 19.1 million concerned insulin. Total production for the year 1955 was estimated at Kr. 120 million.

Swiss Firm's Capital Expansion

One of the leading Basle chemical firms, Lonsa S.A., is to raise its capital from S.F. 40 million to S.F. 50 million to finance the expansion of the hydro-electric power station at Randa Ackersand, a subsidiary interest of the Basle concern.

Brazil's Plastics Industry

Further evidence of the growth of Brazil's plastics industry comes with the announcement that two North American industrial firms, the Union Carbide & Carbon Corp. and W. R. Grace and Co. (the latter with German assistance) have completed separate plans to build polyethylene plastics plants in Brazil.

Canadian Natural Gas

The Canadian Government has announced that it is prepared to finance Trans-Canada Ltd. in building the western section of the Alberta-Montreal natural gas pipeline this year. Mr. Howe, Minister of Trade and Commerce, told the House that "a substantial sum, not to exceed 90%, would be advanced at 5% interest per annum."

Cellulose Plant Opened

SAIC Corporation (South Africa) opened its plant for the production of cellulose from eucalyptus wood during the year. Snia Viscosa's holding in this company has now been transferred to Courtaulds, subject to the Company's right to purchase cellulose on special terms.

Coolant for Transformers

Monsanto Chemicals is carrying out tests to determine the temperature limits that can be tolerated by their new transformer coolant "Aroclor" 1248. The highest temperature possible with present oil-cooled units is 120°C, but Monsanto expect that Aroclor 1248 will raise this to a maximum of 200°C.

German Plastics Expansion

The unusual rate of expansion in the plastics industry in the German Federal Republic during the past few years was fully maintained in 1955 with an increase in output of 28% to a total of 425,000 tons. Polymerisation products, notably PVC, polyethylene and acrylates showed the most striking development whilst cellulose derivatives with an advance of only 15% tended to lag behind the general advance. Considerable extensions to production capacity were made by most of the large manufacturers. The value of exports of plastics rose by 36% to a total of D.M. 298 million and for the first time exceeded the exports of the staple products of the German export trade in chemicals—coal-tar dyestuffs, pharmaceuticals and nitrogenous fertilisers.

Spanish Fibre Plant

Seda de Barcelona, S.A., plans to invest some 76 million pesetas in a plant for the manufacture of polyamidic fibres and synthetic materials. A new industry for the annual manufacture of 50 tons of cut fibre is also contemplated.

Mexican Fertilisers and Insecticides

A fertiliser plant is to be constructed in Monclava, Coahuila, Mexico, which will use the by-products of the nearby coking industry. The estimated cost of the plant is 156 million pesos which is being found by joint Mexican-French interests. In addition to this, an ammonia plant for the production of fertilisers is being built in Guaymas, Sonora, by the local firm Petroquimica, S.A. The plant should be operating before the end of 1957. Finally, an insecticide plant is to be built at Tampico, Tamaulipas, at a cost of 70 million pesos.

New Permali Factory

A new factory, Permali Inc., at Mount Pleasant, near Pittsburgh, U.S.A., is the 21st subsidiary company to be formed by the Permali group. The factory will meet the increased demand for densified wood laminates by American users.

Research Powder Bank

A unique Particle Bank — with deposits ranging in size from milligrams to pounds of selected powder samples—has been established by Stanford Research Institute. The bank is accumulating and distributing a wide variety of powders for research uses by university, industrial and governmental laboratories.

British Rubber Project

Mr. Harvey Firestone, chairman of Firestone Tyre and Rubber, has announced that his company plans to join the Goodyear, Dunlop and Michelin companies in building a synthetic rubber works near Southampton. The plant will have a capacity of some 50,000 tons a year and should be completed late next year as part of a plan to meet the increasing demand for rubber in western Europe.

Belgian Fertilisers for China

Comptoir Belge de l'Azote (Cobelaz) the Belgian sales organisation, which groups all the domestic fertiliser producers, is reported to have received a contract to supply 425,000 tons of sulphate of ammonia fertilisers to China.

New Weed Killers

Four new weedkillers have been put on the U.S.A. market. These are Alanap (n-1 naphthyl phthlalamic acid with urea, Naugatuck Chemical Co.); Neburon (1-n-butyl-3-(3,4-dichlorophenyl)-1-methyl urea, Du Pont); sodium arseno-acetate (W. A. Cleary); cacodylic acid (Cleary). The last chemical is applied as a post-emergence spray at the rate of only three-quarters of a pound per acre, and at that concentration is effective against America's notorious crabgrass.

Venezuela's Petrochemicals

The Venezuelan Government is financing the construction at Moron, near Puerto Cabello, of an ambitious petrochemical undertaking. The total cost of the first phase alone will be in the region of £12 million, £8.5 million of which has already been made available. Production will include fertilisers, explosives, synthetic resins (phenolic, alkyd and vinyl) chlorine, sodium hydroxide and products such as chlorinated aromatic and aliphatic hydro-carbons. Insecticides, weed killers (including selective weed killers) etc., will also be manufactured.

BCE 167 for further information

FERRANTI ELECTRONIC DIGITAL COMPUTERS

FERRANTI MARK 1* COMPUTER

FERRANTI PEGASUS COMPUTER

Ferranti Ltd. are making computers suitable for a wide variety of applications in the fields of mathematics, engineering, science, commerce, accountancy and general statistics. We will investigate the problems of using computers in any of these fields, and advise on the specification of suitable machines.

Write for full information to Ferranti Ltd., Computer Dept., Moston, Manchester 10, or the London Computer Centre, 21 Portland Place, London, W.1.

FERRANTI MERCURY COMPUTER

FERRANTI LTD · MOSTON · MANCHESTER 10

London Computer Centre: 21 PORTLAND PLACE, W.1.

FERRANTI

PLANT EQUIPMENT NEWS

Heat Resistant Belting

Outstanding heat resistance has been proved by conveyor belts fabricated in a new elastomeric material, with a working life more than twice that of the best belting previously available. On one plant in the U.S.A. it has been used for lifting hot salt at a temperature of 150-260°C from a rotary drier to the storage bins above (see illustration). In addition to various forms of conveyor belts for hot and corrosive materials, gaskets and packings made from sheets of "Hypalon" — chlorosulphonated polyethylene — have given fine service during extensive field trials, under many varied conditions. **Durham Raw Materials Ltd., 1-4 Great Tower Street, London, E.C.3.**

BCE 197 for further information

New Surface Coating

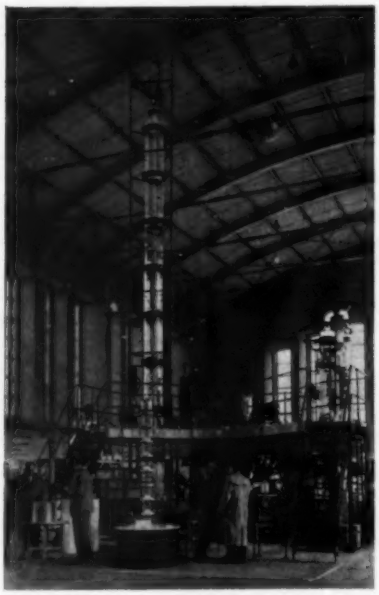
A new surface coating, based on epoxide resins has been developed with the chemical resistance of vitreous enamel, with which it is often impractical and very costly to coat large items of equipment by firing at a temperature of 1500°F. Orthodox stoving finishes are uneconomic where large castings are to be enamelled owing to handling difficulties and the high cost of heating up large masses of metal in the stove. Cellulose lacquers because of their low solid content require a large number of coats to obtain a satisfactory film thickness, and one prone to loss of plasticiser leading to increased brittleness and reduced adhesion. E.P.I. paint finishes may be applied by spray-gun or brush-wise and have good resistance to hot caustic soda solutions, most medium-strength inorganic acids and organic solvents which are especially harmful to normal industrial finishes.

The E.P.I. paint finishes are manufactured by Charles Turner & Son Ltd. in association with Oliver Pragnell & Co. Ltd. and are based on epoxide resins marketed by Shell Chemicals. **Charles Turner & Son Ltd., 165 High Holborn, London, W.C.1.**

BCE 198 for further information

Glass Towers

Q.V.F. are now offering glass absorption, fractioning and wash towers up to 18 in. in diameter. This equipment is suitable for use under full-vacuum conditions and for positive pressures up to 6 lb./sq. in. gauge. It can be assembled in units 3 ft. in



length which makes for easy fabrication on site. Pipe-work in glass section may also be used with equipment either in glass or in other suitable corrosion resistant materials. **Q.V.F. Ltd., Mill Street, Stone, Staffs.**

BCE 199 for further information

Nife Safety Lamps

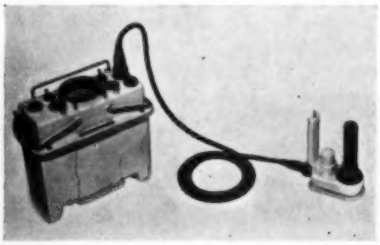
Two new lamps for use in dangerous atmospheres have been developed by Nife Batteries. Based on the well-known Nife Miner's Caplamp, they can be operated with perfect safety in heavy concentrations of hydrogen, coal gas, coke oven gas, blue water gas and other gases of the pentane and petroleum groups. **Nife Batteries, Redditch, Worcs.**

BCE 200 for further information

Seen at the Physical Society Exhibition

Contamination Meter

Designed to measure accurately Gamma activity on clothing, benches, etc., in milli-roentgens per hour at a given distance, the Philips Contamination Meter Type 1092D is extremely portable and will operate from a number of different power sources: (1) a high tension battery; (2) a mains unit; and (3) a vibrator unit. The instrument consists of a counting rate meter using a halogen-quenched Geiger-Müller counter mounted in a probe. For very low counting rates earphones are provided to augment the visual logarithmetic scale. Cold cathode valves are used throughout to make filament heating, from an attendant source of supply, unnecessary. **Philips Electrical Ltd,. X-Ray Division, Century House, Shaftesbury Avenue, London, W.C.2.**



BCE 201 for further information

Oxygen Meter

Dissolved oxygen in the feed water is probably the greatest promoter of pitting-type corrosion in high pressure boiler installations. It is therefore necessary to measure continuously and accurately the concentration of oxygen over the range 0-0.2 cc/litre. The Baker Platinum Hersch oxygen meter has been developed for this purpose; in addition it measures any change in concentration due to a deaerator failure or leak within a minute of its reaching the sampling point. The meter does not have any moving parts likely to require maintenance and operates without the addition of an electrolyte to the water under test. **Baker Platinum Ltd., 52 High Holborn, London, W.C.1.**

BCE 202 for further information

TONNAGE OXYGEN PLANTS

and gas separation plants

British Oxygen Linde offer the combined experience and technical resources of two great companies —The British Oxygen Company Limited and Linde Gesellschaft— designers and manufacturers of oxygen, nitrogen, and gas separation plants for more than fifty years.

BRITISH OXYGEN LINDE LIMITED

Bridgewater House, St. James's, London, S.W.1

PLANT EQUIPMENT NEWS

Viscosity Poisemeter

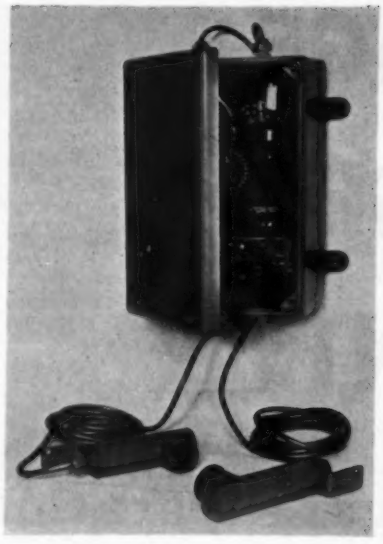
It is well known that viscosity may be used as a process control variable in the chemical engineering and allied industries. The Dobbie-McInnes Poisemeter has been developed to record viscosity continuously on the plant, without the necessity of taking samples for testing in the laboratory. This results in a saving of both time and through-put material, which might be wasted. The viscometer consists of an electric motor driving a drag member —usually a disc, paddle or cross-bar —within the fluid to be measured. As the viscosity varies a current change in the motor circuit produces a reading on either a milliameter or potentiometer circuit. This is proportional to the logarithm of the dynamic viscosity. The instrument has been successfully used, with the following materials: lubricating and fuel oils, resins, plastics and paints. As the viscosity of some liquids change very critically with a slight change of temperature

the instrument may be fitted with an automatic temperature compensation circuit to record at a definite reference temperature. **Dobbie McInnes Ltd., Broomloan Road, Glasgow, S.W.1.**

BCE 203 for further information

Extension Projectors

In applications where the amount of factory space is limited, or where a beam of small cross-section is required up to ranges not exceeding 6 ft. in length, extension photoelectric equipment is recommended. The main advantages are that the extension heads only need be mounted at the



position where the beam is required and the control unit positioned up to a distance of 10 ft. from the heads. The projector may be either separate from or enclosed within the photocell head case. In the latter case, it is especially suitable for oil flame failure detection applications when a short delay of approximately ½ second is incorporated to overcome the possibility of false operation due to slight flame flutter. **Londex Ltd., Anerley Works, 207 Anerley Road, London, S.E.20.**

BCE 204 for further information

Seen at the Mechanical Handling and Production Exhibition

Moulded Pack Material

Designed to replace straw, woodwool and similar materials, Protecco-pack is especially suitable as a packing material, resistant to the bedding down action caused when handling heavy objects. The material consists of shavings bonded with synthetic resins, and because of its moulded shape may be used a number of times. Under test, standard Winchester bottles, full of liquid, have been dropped on to concrete from a height of 50 ft. and in every instance the moulds have offered complete protection. **Proteccopack Ltd., Ditton Road, Widnes, Lancs.**

BCE 205 for further information

Nylon Slat-Conveyor

Combining great tensile strength, lightness (it weighs about one-eighth of stainless-steel per unit volume), with resistance to most acids and alkalis, a very low coefficient of friction nylon offers unique properties as a conveyor material for specific jobs. Cleanliness, ease of sterilisation, the fact that it is unnecessary to lubricate, are advantages very suitable for the pharmaceutical, food and drink industries. Conveyors are available up to 7½ in., although this could easily be increased, and the slats are joined by stainless steel pins. Under tests the nylon conveyor has showed that it will carry a load as great as that carried by a similar stainless steel chain. **British Rawhide Belting Co. Ltd., 246-8 Gt. Portland Street, London, W.1.**

BCE 206 for further information

Blanket Conveyor

The slope of conveyor belts is often limited by the angle of repose of the material being handled; but the design of plant layout may require a slope which cannot be achieved by conventional belt arrangements. The Blanket conveyor by employing the principle of a second belt enables gradients of 45° to be reached. In practice the material is held firmly between the belts and elevated without spillages, thus preventing any possible dust nuisance and removing the necessity of continuous skirt plates in open gantries. At the feed point the carrying belt is inclined at the normal angle with the conventional feed chutes and skirt plates, whilst beyond this the blanketing belt comes into operation. **W. J. Jenkins & Co. Ltd., Retford, Notts.**

BCE 207 for further information

New Hose Fittings

Goodyear announce a new range of fittings for their chemical resistant hose which is available in sizes up to 12 in. diameter and 50 ft. in length. The beaded end—fabricated in one piece with the length of pipe—and its split (malleable iron) retaining ring provide a secure conplug with no metal parts exposed to abrasion or corrosion and maximum free length for bending. Installation is easy as the rings can be rotated to line-up the bolt holes without twisting the hose, which has the advantage that the hose-lengths can be turned occasionally to reduce concentrated localised wear to a minimum. For higher pressure work the full face flanged end hose is used. It is of integral construction such that no metal parts are exposed to abrasives or corrosives liable to cause their premature failure. Fabrication on site is remarkably easy and being flexible does not raise any problems of alignment or expansion due to temperature increases. Its resistance to chemical

We delved into Kaolin clay....

. . . and came up with this faster way to dewater it

Kaolin clay processing is largely a matter of slurrying, settling in tanks and dewatering in large quantities.

One of the first jobs is to separate the clay into particle size ranges for various purposes and Sharples centrifuges are already widely used in this classification operation. The finest of these grades is the clay for coating fine quality printing papers. It is in the final processing of this fine fraction clay slip that we at Sharples were asked to help.

First the fine fraction slip can be flocculated by sulphurous acid, then settled by gravity to a concentration of 20% clay solids. Then comes the difficult and expensive process of dewatering by filter press to 65% solids ; especially expensive since the filter press has to be constructed of stainless steel to withstand the corrosive nature of the slurry.

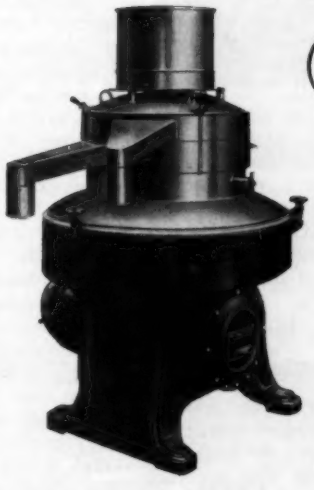
Doubling the capacity of the filters

After experimenting with various Sharples centrifuges, we found a method whereby Sharples Nozljectors would dewater the clay slurries from 20% to 40-50% solids continuously and at high throughput capacities. In this way, the clay producer could at least double the capacity of his filters by pre-thickening the clay slip fed to a filter. The Nozljector-filter press combination could then handle a given clay throughput at a substantially reduced capital investment, and with great economy in ground space requirements.

Unique Engineering Service

Kaolin clay is only one example of the Sharples Centrifugal Engineering Service in action. Whatever your separation problem may be, Sharples experts are always ready to investigate and advise. Sharples is the only concern in Britain able to offer a complete range of centrifugal machines for any separation purpose, so you can be sure of unbiased advice.

Write to us and we'll be glad to send you further details of our equipment and of our technical advisory service, or, if you wish, 'phone Amberley 2251/3 and talk to Martin Trowbridge about your problem.



The Sharples DH-2 Nozljectors give continuous separation of solid and liquid phases. Just one machine in the Sharples range. Send for Bulletin No. 1259M

SHARPLES

ALWAYS TURN TO SHARPLES

SHARPLES CENTRIFUGES LTD., WOODCHESTER, STROUD, GLOS.

Telegrams : 'Superspin' Stroud
Telephone : Amberley 2251/3

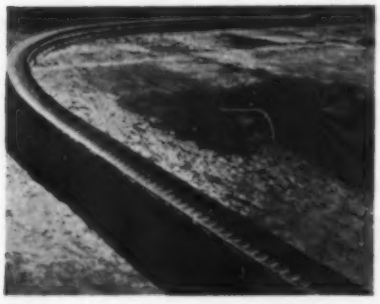
PLANT EQUIPMENT NEWS

action makes it applicable to the many branches of the chemical industry, bleaching, gas and coke by-products, refineries, salt works, fertiliser factories and tanneries. **The Goodyear Tyre & Rubber Co. (Great Britain) Ltd., Industrial Rubber Products Department, Wolverhampton.**

BCE 208 for further information

Hot Materials Conveyor

Constructed from segments of steel plate, bent in a trough-shaped form, running on small wheels on a steel track, the W.S. Steel track conveyor can handle materials at temperatures of up to 900°F. This conveyor with an effective width of 31 in., can operate on curves with a radius as small as 30 ft. and transport coal at a rate of



280 tons per hour. Less than 30 in. over-all height, with easily interchangeable sections, it has already found considerable use in the following industries: coal-mining, quarrying, iron and steel making, chemical industry and cement plants. **Wharton Engineers (Elstree) Ltd., Watford Road, Elstree, Herts.**

BCE 209 for further information

High Speed Screens

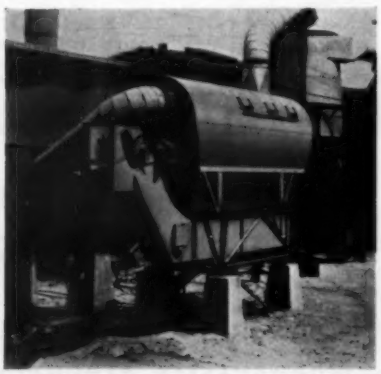
The range of materials which may be handled by a vibratory screen is considerably increased if the angle of the screen can be varied. This fact has led to the introduction of the variable angle Viking high speed vibratory screen by W. J. Jenkins & Co. Ltd. The screen cloth is of welded mesh or perforated plate construction and held in position by rubber faced runners and wedges in special section side members to facilitate quick changing. The vibrator unit is mounted below the screen and is adequately protected from the material being handled. The drive may be arranged on either side and be placed either to the front or rear of the vibrator shaft. Absorption of the vibration between screen and supports is by four heavy duty silent

bloc rubber bushed mountings—which can be changed without disturbing any part of the frame or vibrating unit—on a horizontal base. On screens supplied for handling abrasive or corrosive materials, all exposed surfaces are coated with rubber or plastic. The angle is fully adjustable from 5° to 30°. **W. J. Jenkins & Co. Ltd., Retford, Notts.**

BCE 210 for further information

The Air Tumbler

The most desirable characteristics of dust removal plant are high efficiency of collection and low operating costs. The Air Tumbler has both qualities. Air is drawn into one end of the barrel under suction from the exhaust fan connected to the outlet at the opposite end. During its flow through the barrel—the lower part of which contains water—dust is continuously centrifuged through four revolutions along a helical path formed by the screw. Air impingement on the surface of the water causes a sheet of water to flow round the periphery of the barrel bringing down the dust to the sludge-removal chamber. Pressure drop is reduced to a minimum because of the lack of constriction applied to the air flow through the equipment. In addition to cleaning the air, the Air Tumbler recovers the dust in a sludge which may have a valuable



reclaim value, one unit in operation recovers $4,000 worth of gold per month. **Acme Ventilating Ltd., 22 Hans Road, London, S.W.3.**

BCE 211 for further information

Carrier with Crane

Two versions of the Straddle Carrier are now fitted with a hydraulically operated crane. It is now possible, therefore, for the driver to unload direct from a road vehicle, railway wagon or stacks, transport the load to the new destination where a similar reverse procedure may be carried out. One special application is for pipe-laying, since pipes brought to the site by Straddle Carrier can be removed

individually by means of the crane and lowered directly into a trench.

The crane has a capacity of up to 30 cwt. according to the outreach and can be slewed through an angle of 180°, enabling loads to be negotiated at the front and to each side of the Carrier. The height of lift is from 2 ft. 7 in. to 15 ft. 9 in. above ground level, with the jib fully extended. Safety devices are incorporated to prevent overloading, overhoisting and overslewing, whilst a further safety device prevents the dropping of a load in the event of hydraulic circuit failure. **British Straddle Carrier Co. Ltd., 7 Chesterfield Gardens, Curzon Street, Mayfair, London, W.1.**

BCE 212 for further information

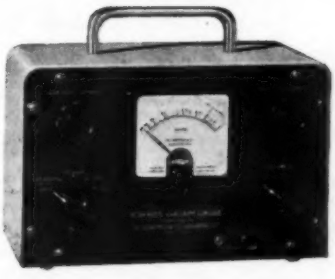
Load/Unload Cradle

Handling carboys of concentrated acids and other vessels containing dangerous materials is often a hazardous problem in the chemical industry. By means of the Mackaness Vertiswing it is possible to swing loads up to 3 cwt. without spillage from ground level to the floor of a vehicle or to a platform—or vice versa. The cradle can operate at rates of up to five loads a minute, whilst additional attachments—to handle either sacks or drums lengthwise—may be fitted to the basic hydraulic unit in place of the cradle. **A. J. Mackaness Ltd., Billing, Northants.**

BCE 213 for further information

High Vacuum Technique in . . .

CHEMICAL ENGINEERING



Applied vacuum techniques in chemical engineering are yielding new materials and processes or greatly improving old methods.

EDWARDS specialise in designing and manufacturing every type of equipment connected with vacuum processing, which include . . .

ROTARY PUMPS

A complete range available with capacities and speeds available to suit the smallest laboratory or largest industrial project. A unique AIR-BALLASTING device enables the pump to handle condensable vapours without contamination.

VAPOUR PUMPS

A range of oil, mercury and silicone models from 1" (25 mm.) to 24" (610 mm.) for the *HIGHEST* vacuum duties. Also 'Booster' pumps for *maximum* speeds in the industrial range.

VACUUM GAUGES

From simple manometers to highly precision all-electric gauges for *every* application of vacuum.

VACUUM & FREEZE DRYING UNITS

A complete range of laboratory and production capacity models for the drying or concentration of all heat-sensitive materials.

★ *May we help you with any problem connected with . . .*

- DEHYDRATION
- SUBLIMATION
- DISTILLATION
- FILTRATION
- CONCENTRATION
- IMPREGNATION
- CHEMICAL ANALYSIS

For better vacuum service . . .

EDWARDS HIGH VACUUM LTD

MANOR ROYAL · CRAWLEY · SUSSEX CRAWLEY 1500 (10 LINES) EDCOHIVAC CRAWLEY

BRANCHES: GLASGOW · TORONTO & MILAN

AGENTS THROUGHOUT THE WORLD

Book Reviews

The Chemical Constitution of Natural Fats. Third Edition revised and enlarged.

by T. P. Hilditch

644 pp., Chapman and Hall Ltd., London, 1956, 95s.

PROF. Hilditch is an authority on the chemistry of natural fats and with his collaborators has greatly contributed to our understanding of this subject. The third edition of this valuable book includes important results published up to 1955. It has retained the general plan of the previous editions, which is based on the established relationship between the biological origin of fats and their physical and chemical characteristics.

The author introduces the reader into the subject unhurriedly, providing him with a clear definition of the types of fats and a realisation of the difficulties encountered in their quantitative investigations because of their remarkable tendency to exist as mixed triglycerides. The treatment of component acids of fats of aquatic and terrestrial plants and animals is comprehensive and includes the curious platypus whose fat, though mammalian, resembles in composition that of a freshwater fish—an interesting case of adaptation. An evolutionary point emerges from a study of the component fatty acids of the reserve fats of amphibia and reptiles which prove to be intermediate in character between those of the reserve fats of aquatic and of land animals. An extended treatment of component acids of the fats derived from seeds or fruit coats of the higher land plants provides a wealth of information on the sources of the important palmitic, oleic and linolenic acids. The examination of component glycerides is equally comprehensive and is accompanied by a review of the quantitative methods for the determination of glyceride structure. It is in this field that the greatest advance has occurred since the publication of the previous editions, and the author has rewritten the relevant chapters. The biosynthesis of fats in plants and animals (from carbohydrates), the chemistry of saturated and unsaturated fatty acids and the synthesis of glycerides are also dealt with in detail. The book is concluded with a description of experimental methods used in the quantitative investigation of natural fats.

The rich material contained in this book is presented with great lucidity of expression and the text is free from disconcerting digressions. The author emphasises throughout the dynamic character of the subject (the book abounds in reference to original papers) and shows clearly the path to further progress. Bibliography is excellent, typography, format and binding are good. The price of the book is reasonable considering its size and the store of information contained therein. The book can be warmly recommended as a textbook and as a reference book. It will decidedly prove of interest to organic chemists and invaluable to those engaged in the chemistry of fats.

M. Pianka

Quantitative Methods of Organic Microanalysis

by S. J. Clark, Ph.D., A.R.I.C.

251 pp., illustrated. Butterworths Scientific Publications, 1956, 30s.

THIS book, dealing as it does with that section of microanalysis which is becoming of rapidly increasing importance in industrial laboratories would be welcome if it were of average quality. In fact it is much more than that. It is evident that a good deal of clear thinking and hard work has gone into the preparation and presentation of the book and it reflects throughout the practical outlook of the author. The style is simple and direct and is that of a man who has spent much time at the bench and is well acquainted with the small, everyday, but vital snags which occur there. This is not a text for the newcomer to microanalysis, but should be of great value to those who have a working knowledge of the classical techniques and are interested in the progress and modern outlook of the science.

Older and newer methods are compared and the reasons why one or the other is preferred are clearly stated, except in those cases where the author considers that insufficient evidence has, as yet, been accumulated and then he does not hesitate to give an open verdict. No claim is made that microanalysis is a short cut to "push-button" analysis, but it is inevitably borne in upon the reader that for routine analytical procedure there is a good deal to be said for the micro method. The book is illustrated with over 100 line drawings which are, for the most part, admirably clear, but are marred by the exceptional case in which parts of the legend are ambiguous. The references are up to date and the index adequate.

B. D. Owen

Chemical Pilot Plant Practice

by D. G. Jordon

152 pp., illustrated. Interscience, New York and London, 1956, 28s.

THIS little book, as was the author's intention, may be considered as a pilot book on the subject, and no more. The style of the book is informal, and at times colloquial. The first chapter discusses general considerations, which includes a proportion of non-technical matter, such as "human qualities" of personnel required for successful pilot plant practice. The second chapter, "the scale-up problem", presents, however, the essence of the subject matter of mechanical and chemical similitude in a useful though limited way, collating current views and giving the significant literature references. It is interesting to note the emphasis on the scale-up of mixing systems which, of course, enter into a large number of chemical engineering operations and processes. It is a pity that data from some early work on mixing brine and water in the incorrectly chosen paddle arm mixer still has to be used. Next comes a discussion of the handling of liquids, solids and gases on the pilot-plant scale. Here the author makes the important point that, though the pilot plant itself may be set up correctly, material handling to and from it is often inadequately considered, resulting in confused arrangements. A typical photograph supports this contention.

Pilot plant chemical reactors, including the now important fluid-bed catalytic reactor, are discussed in the fourth chapter. A group of unit separations in a chapter headed Separation Processes are considered in their pilot plant practice. The author distinguishes those operations which are amenable to direct design from laboratory data through a sufficiency of fundamental knowledge; and those which, of necessity at the present stage, should go through pilot plant. This distinction requires more explanatory matter than has been given, as this is the most contentious part of the whole subject. The last chapter is on Cost Estimation and Report Writing. The layout of the book is pleasing, though the price is somewhat high for a slender volume with only 17 illustrations.

R.J.C.

The first word in FILTRATION

- FILTER BAGS
- TUBES
- CENTRIFUGES
- CLOTHS
- SOCKS
- POCKETS
- STOCKINGS
- CANDLES

May we arrange for our technical representative to show you our range of all the latest materials, both natural and synthetic for the above uses.

Cotton Bros.

COTTON BROS. (LONGTON) LTD.
Crown Works, Portland Road
LONGTON Staffordshire
Telephone : LONGTON 33021 (3 lines)
Telegrams : "COTBRO" Stoke-on-Trent

CHAPMAN & HALL

★ *Four New American Books* ★

AUTOMATIC PROCESS CONTROL
FOR CHEMICAL ENGINEERS

by

Norman H. Ceaglske
(Professor of Chemical Engineering, University of Minnesota)

9¼" x 6" 228 pages Illustrated 54s. net

This book presents and applies the basic mathematical principles of process control in an elementary form. It is written directly for chemical engineers—on the theory that they cannot have a fully rounded knowledge of their profession unless they are familiar with the fundamentals of automatic control.

CHEMICAL SAFETY SUPERVISION

by

J. Guelich
(General Chemical Division, Allied Chemical & Dye Corpn.)

9" x 6" 227 pages Illustrated 36s. net

An extremely practical handbook for all who manufacture, handle or use chemicals. With the aid of numerous illustrations it presents tested, proved methods of reducing chemical hazards in works and laboratories.

FLUID FLOW IN PRACTICE

Edited by

J. R. Caddell
(E. I. du Pont de Nemours & Co., Wilmington, U.S.A.)

7½" x 5½" 127 pages Illustrated 24s. net

A collection of papers originally presented at the third 'Experience in Industry' Symposium, sponsored jointly by the Philadelphia-Wilmington Section of the American Institute of Chemical Engineers and the University of Pennsylvania.

MODERN CHEMICAL PROCESSES
(Volume IV)

by the Editors of

"Industrial and Engineering Chemistry"

11½" x 8" 208 pages Illustrated 40s. net

The fourth volume in a series likely to prove a perpetual inventory of American chemical technology and a most valuable reference source of its kind. This volume contains descriptions of nineteen recently developed chemical processes, all now in operation on a full-scale production level.

You are invited to write for our "CHEMICAL TECHNOLOGY LIST" which includes upwards of 100 books on Chemical Technology and allied subjects

37 ESSEX STREET · LONDON, W.C.2

The Month's News in Brief

News Briefs

Esso Petroleum Company Ltd. announced today that the name of its research affiliate company in the U.K. has been changed from Esso Development Company Ltd. to Esso Research Ltd. This step has been taken so that the name will reflect more accurately the company's varied and expanding activities in the field of petroleum research. The company's head office will remain at 33 Davies Street, London, W.1, where Mr. C. S. Windebank, managing director, will have his headquarters.

The Treasury have made an Order which continues for a further period of one year from 13th May, 1956, the exemption from duty under the Import Duties Act, 1932, of certain forms of nickel and ferro-nickel alloys imported in the forms described in the Schedule to the Import Duties (Exemptions) (No. 3) Order, 1955 (S.I. No. 676).

In co-operation with the Science Museum, South Kensington, the British Iron and Steel Federation is to create a new ferrous metallurgical display in the Museum to commemorate Sir Henry Bessemer. For this purpose the sum of £50,000 has been allocated.

An annual university scholarship in chemistry or chemical engineering is to be provided by Thomas Hedley & Co., to be competed for by its employees. The scholarship will be awarded each year for an Honours course at King's College, Newcastle upon Tyne.

The council of Leeds University have acknowledged a further donation of £21,000 from Brotherton and Company to the building fund for the chemical engineering section of the Department of Coal Gas and Fuel Industries which during the past 12 months has received £81,660 from industrial firms interested in schemes for the development of higher technological education. The cost of the new building will be £615,000, of which the Government, through the University Grants Committee, will find £450,000. It is hoped to occupy the new buildings in session 1958-59. The council also announced the appointment of Mr. R. J. R. Hayward, B.A. (Oxford), B.Sc. (London), as Brotherton Lecturer in Inorganic and Structural Chemistry from a date to be arranged.

The American Can Company's research department claims to have developed a new process for soldering cans that will reduce tin consumption by some 2600 tons annually.

Extensions costing over £150,000 to Shell's agricultural research centre at Woodstock, near Sittingbourne, Kent, were opened by Sir William Slater, secretary of the Agricultural Research Council.

A unit to co-ordinate research in South Africa into the prevention of occupational diseases caused by airborne dust has been established by the Council for Scientific and Industrial Research.

Shaw Petrie Ltd./Clyde Tube Forgings Ltd., a Scottish firm making and erecting pipe fittings for projects all over the world, celebrated its 21st anniversary on Friday, 11th May, this year.

The 1957 British Industries Fair will be held at Castle Bromwich, Birmingham, from the 6th to the 17th May.

An investigation of the diffusion rate of hydrogen through ceramic-coated nickel has recently been completed by J. R. Cuthill and R. W. Dixon of the National Bureau of Standards. The study reveals that the ceramic reduces the hydrogen flow by a factor of about 20. The results indicate that it would be worthwhile to apply ceramic coatings to the metallic parts of high-temperature devices to minimise the diffusion of hydrogen into otherwise hermetically sealed systems.

Applications for grants from the Research Fund of the Chemical Society will be considered in November next and should be submitted on the appropriate form not later than Thursday, 15th November, 1956. Applications from Fellows will receive prior consideration. Forms of application together with the regulations governing the award of grants may be obtained from the General Secretary, The Chemical Society, Burlington House, Piccadilly, London, W.1.

En route to Sweden the Queen and the Duke of Edinburgh visited the I.C.I. Wilton Works. They were conducted round the works by Sir Alexander Fleck, who was accompanied by Mr. Donald Scott (group director responsible for Wilton and Billingham), Dr. Caress (chairman of I.C.I. Fibres Division), Mr. C. M. Wright (chairman of the Wilton Council) and other senior officials. During their tour they saw part of the Terylene plant and a special Terylene exhibition.

Atomics

The American Atomic Energy Commission has approved plans for a 236,000 and a 180,000-kilowatt atomic power stations.

The Harwell "reactor school" is to be enlarged to enable an additional 30 students to be passed out every three months. This will bring the quarterly total up to 60.

A site on the Severn Estuary at Berkeley, near Bristol, has been chosen for an atomic power station. This was announced by Mr. A. C. Thirtle, controller of South-Western Division of the Central Electricity Authority who further stated that he thought work would commence on the Berkeley site about mid-1957 and be ready for initial operation by the end of 1960.

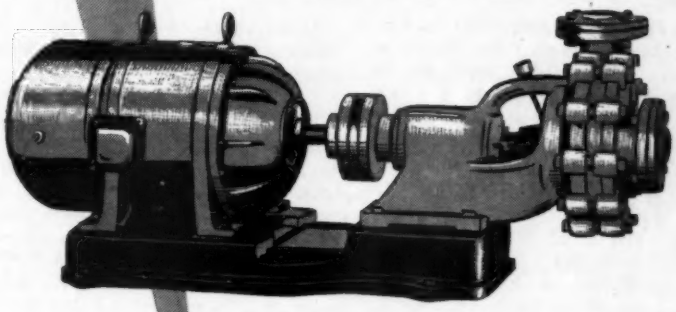
A Geiger-type counting device on show at the recent Physical Society Exhibition was of such dimensions that all the components could easily be accommodated into a 20 cigarette packet. Designed by A. R. Gould, of the Atomic Weapons Research Establishment, the device is reported as suitable for use in all situations where injurious radiation may be expected.

People

Major W. R. Brown, D.S.O., has been elected vice-chairman of the Power-Gas Corporation Ltd.. **Mr. T. K. Hargreaves,** D.S.O., M.A.,

Mr. John A. Oriel, president of the Institution of Chemical Engineers, presenting the William Macnab medal to J. D. Howie.

PUMPS FOR THE CHEMICAL INDUSTRY



TYPE DZT

For flooded suction duties over a wide range of applications incorporating our own corrosion resistant alloys.

AGENTS THROUGHOUT THE WORLD

BRITISH LABOUR PUMP CO. LTD.

BRITISH LABOUR PUMP CO. LTD., BLUNDELL ST. LONDON, N.7

Telephone: NORth 6601-4

The Micronizer

for grinding to micron sizes

IS FLEXIBLE

It grinds dry solids to sub-sieve sizes and the lower micron ranges, small quantities of valuable materials or large tonnages of commercial products.

IS VERSATILE

It handles with equal success materials that are heat-sensitive or very hard substances.

IS ORIGINAL

It does a job where conventional grinding methods cannot be employed and achieves high-speed reduction to the micron particle size distribution required.

Micronizer Mills or complete installations produced to customers' requirements.

Commission micronizing undertaken at our plant near St. Albans, Herts.

F. W. BERK & Co., Ltd.

Micronizer Plant Dept.,
P.O. Box 193, 1/19, New Oxford Street, London, W.C.1
Tel.: MUSeum 0934

BCE 174 for further information

A.M.I.Mech.E., has also been appointed a director of the company.

Mr. W. Lindsay Burns has relinquished his post as managing director of Henry Balfour & Co. Ltd. after twenty-seven years' service. His place has been taken by **Mr. Lindsay Burns, jun.,** and **Mr. I. M. O. Hutchison,** who will be joint managing directors. Mr. W. Lindsay Burns remains as Chairman and will act in a consulting capacity.

The Lord President of the Council announces with regret that **Sir Hugh Beaver** has expressed a wish to resign from the Chairmanship of the Advisory Council of the Department of Scientific and Industrial Research. Sir Hugh Beaver will continue to serve as a member of the Council. **Sir Harry Jephcott** has accepted the invitation of the Lord President to become Chairman.

Sir Harry Jephcott *W. Lindsay Burns*

The appointment of **Mr. John G. Thom** as Sales Manager for Northern Ireland is announced by British Oxygen Gases Ltd.

Dr. R. A. Wilkins, vice-president, Research and Development, Revere Copper and Brass Inc., Rome, N.Y., U.S.A., has been elected a Fellow of the Institute of Metals in recognition of his outstanding services to the Institute, in particular as Corresponding Member to the Council in the United States. Election to the Fellowship is the highest honour bestowed for services to the Institute itself and Fellows are limited in number to twelve. Dr. Wilkins is the first member resident outside the British Isles to be elected to the Fellowship.

Sir John Cockcroft, director of the Harwell Atomic Energy Establishment, has been awarded the Kelvin Gold Medal for 1956 by the Institution of Civil Engineers. The medal is awarded every three years "as a mark of distinction in engineering work of the kinds with which Lord Kelvin was especially identified."

The Chemical Society presented **Professor Otto Hahn** with its Faraday Medal at the annual general meeting held in Nottingham recently.

The Council of the Society of Dyers and Colourists recently announced the award of the Perkin Medal to **Mr. J. R. Whinfield** for the discovery of "Terylene".

Sir Harold Smith, chairman of the Gas Council, is to receive the Birmingham Medal, the highest award of the Institution of Gas Engineers, in recognition of his career as a chartered gas engineer and his services to the gas industry.

Mr. Julian M. Leonard has been reappointed president of the Society of Chemical Industry for 1956-7. **Dr. H. Levinstein** and **Sir Eric Rideal** have been appointed past presidents, members of Council, and **Mr. G. O. Curme** and **Professor H. D. Kay** have been appointed vice-presidents for the term 1956-59.

The Council of the British Launderers' Research Association has announced the appointment of **J. Leicester,** M.I.Chem.E., A.I.Mar.E., as director. Mr. Leicester takes over his duties at the B.L.R.A.'s Hendon Laboratories on 1st August.

Mr. H. V. Schofield has retired from active duties as sales director of the Chloride Electrical Storage Co. Ltd., he will, however, retain his seat on the Board. **Mr. Edward Powell,** director and sales manager of Chloride Batteries Ltd. since 1951, now becomes general sales manager of the whole Chloride Electrical group, and **Mr. A. C. Stewart,** who was made assistant sales manager last year, now assumes full responsibility as sales manager of Chloride Batteries Ltd.

Lord Cherwell and **Sir Ronald Weeks,** president of the British Scientific Instrument Research Association, two of the men included in the Birthday Honours List, form the subject of a note in this month's Digest. Other names include:

Lord Cherwell *Sir R. Weeks*

Knights Bachelor: **H. W. Clarke,** chairman of the Aluminium Industry Council: **H. S. Gibson,** man. dir., Iraq Petroleum Co., Ltd.; **F. C. Hooper;** Prof. W. J. Pugh, D.S.I.R.

Order of the Bath, Civil Division: **J. Anderson,** ch. scient., Admiralty Signal and Radar Establishment.; **H. S. Gilham,** Asst. Comptroller, Patent Office.

Mr. Trefor Davies *who was recently appointed technical executive officer of A.B.C.M.'s Chemical Engineering Research and Advisory Committee.*

Order of the British Empire, Civil Division: K.B.E.: **Sir Thomas Ralph Merton,** treas. Royal Society: *C.B.E.* F. P. Bowden, Reader in Physical Chem. University of Camb.; **R. M. Currie,** hd. of works study dept., I.C.I.; **L. N. Duguid,** dep. ch. insp. of factories.; **G. V. B. Hereford,** dep. ch. scient. offr., Pest Infestation Lab., D.S.I.R.; **J. Megaw,** mbr. of the Indust. Injuries Adv. Ccl.; **J. D. Peattie,** ch. engr. Cent. Elec. Auth.; **C. Sykes,** man. dir., Thomas Firth & Brown Ltd. *O.B.E.:* **R. A. Browning,** dir. of contracts U.K. Atomic Energy Auth.; **A. H. Lewis,** dir. Jealott's Hill Res. Stn., I.C.I.; **C. A. Masterman,** tech. dir. undergrd. gasificn. trials. Min. of Fuel and Pwr.; **W. G. Sharp,** dir., Armour & Co. *M.B.E.:* **J. B. Brennan,** gen. sec. Instn. of Chem. Engrs.; **J. Crowther,** ch. metallurgist, James Booth & Co.; **K. E. B. Jay,** prin. scient. offr. scient. admin. div., Atomic Energy Res. Estab.; **G. S. Palmer,** mgr. Titanium Melting Plant, William Jessop & Sons.; **R. E. Tugman,** safety offr., Alkali Div., I.C.I.

British Empire Medal, Civil Division: **W. E. Downes,** traffic sup., Shell-Mex and B.P.; **R. Seabrook,** wks. tech. offr., grade IV, Bdg. Res. Stn., D.S.I.R.; **D. H. Smith,** fmn., Shell Refig. & Mktg. Co.

New Publications

Chemistry Research 1955: The report of the proceedings of the Chemistry Research Board for 1955. H.M.S.O. Price 4s.

Outline of Work Study, published by the B.I.M. is the first of three volumes to be devoted to this subject. British Institute of Management, P.O. Box No. 483, 8 Hill Street, London, W.1. Price 3s. 6d.

Titanium No. 1 is a technical leaflet which embodies the finding of research work carried out by British Oxygen Gases in the welding of this metal. Copies available from British Oxygen Gases Ltd., Sales Technical Service Department, North Circular Road, Cricklewood, London, N.W.2.

Neoprene Notebook is a monthly technical and industrial bulletin on Neoprene Synthetic Rubber. Copies are available for interested firms. Durham Raw Materials Ltd., 1-4 Great Tower Street, London, E.C.3.